SEPTEMBER 15, 1920 PRICE 25 CENTS

AVIATION
AND
AERONAUTICAL ENGINEERING

Above the Alps

VOLUME IX
Number 4

Three
Dollars
a Year

SPECIAL FEATURES

PUBLISHED SEMI-MONTHLY
BY
THE GARDNER, MOFFAT CO., INC.
HIGHLAND, N. Y.
HARTFORD BUILDING, UNION SQUARE
22 EAST SEVENTEENTH STREET, NEW YORK
Entered as Second-Class Matter, May 19, 1920, at the Post Office at Highland, N. Y.

Easier to Heat Treat

THE wide hardening range, and the fact that drawback temperatures have little effect between very wide limits, make the heat treatment of Molybdenum Steels simple and reliable. The broader limits afforded mean fewer re-treated parts and a proportionate saving in cost.

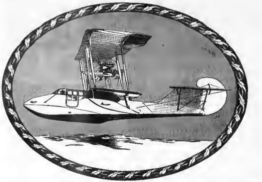
The higher drawing temperatures possible with Molybdenum Steels give ease in furnace regulation and manipulation, while markedly increasing the finished product's resistance to dynamic stress and to fatigue.

Copies of our book, "Molybdenum Commercial Steels" which deals with all processes in the commercial production and use of these steels, will be sent on application to

Easier to Heat Treat
Easier to Machine
Dynamically Tougher
Resist Fatigue

Climax Molybdenum Company—or—The American Metal Company Ltd.
61 Broadway —— New York
Climax Molybdenum Company is the Largest Producer of Molybdenum in the World

PROVEN IN WAR FOR THE TASKS OF PEACE



Taking the Cream of a Great Business

ANY number of business men can see an opportunity after the wise ones have made money at it.

In a few more months the awakening will come—and then everybody will want to be an Aeromarine dealer.

But right now is the time when sales are being made—when territory is being tied up—when the cream of a great business is going to those men of vision who have realized that aviation is here—for good.

Aeromarine travel is simply a matter of getting into a luxurious mahogany silver trimmed and leather padded cabin—in your street clothes—and going swiftly, steadily and surely to your destination, in one quarter the time of land travel and with none of its dust, dirt, and delay.

No wonder the Aeromarine demonstration is the one that sells the prospect every time.

Write us today of dealer opportunities—before the cream of the business has been taken by the men of vision.

Aeromarine

AEROMARINE PLANE & MOTOR CO., TIMES BUILDING, NEW YORK
LARGEST EXCLUSIVE BUILDERS OF FLYING BOATS IN AMERICA

SEPTEMBER 15, 1920

AVIATION AND AERONAUTICAL ENGINEERING

VOL. IX. NO 4

Member of the Audit Bureau of Circulations

INDEX TO CONTENTS

THE GARDNER, MOFFAT COMPANY, Inc., *Publishers*

HIGHLAND, N. Y.

HARTFORD BUILDING, UNION SQUARE, 22 EAST SEVENTEENTH STREET, NEW YORK

SUBSCRIPTION PRICE: THREE DOLLARS PER YEAR. SINGLE COPIES TWENTY-FIVE CENTS. CANADA, THREE AND A HALF DOLLARS. FOREIGN, FOUR DOLLARS A YEAR. COPYRIGHT 1920 BY THE GARDNER, MOFFAT COMPANY, INC.

ISSUED ON THE FIRST AND FIFTEENTH OF EACH MONTH. FORMS CLOSE FIVE DAYS PREVIOUSLY. ENTERED AS SECOND-CLASS MATTER MAY 19, 1920, AT THE POST OFFICE AT HIGHLAND, N. Y., UNDER ACT OF MARCH 3, 1897

THOMAS~MORSE AIRCRAFT CORPORATION

THOMAS~MORSE AIRCRAFT CORPORATION

Money in the Air

Commercial Aviation is on the increase—passenger and freight carrying airlines are being organized all over the country—hard headed business men are realizing the possibilities of aircraft as a means of solid investment—*the Human Interest is there—Everybody Wants to Fly.*

Before selecting your air routes, locations and the right kind of flying craft—learn all you can about Commercial Aviation in the United States—READ

The Aircraft Year Book for 1920

Issued by the Manufacturers Aircraft Association, Inc.

Just a few interesting chapters in this book containing 335 pages of facts about flying. 80 pages of instructive photographs and numerous maps.

Read's Own Story of the Trans-Atlantic Flight.
Complete records of the
Aerial Mail — Sport Flying
Forest Patrol — Passenger Lines
Chronology of 1919 in Aviation
U. S. Army Air Service Victories
How the World has been two-thirds flown around in the past year.
List of Permanent and Emergency Landing Fields in the U. S.
Map of World's Air Routes
Map of U. S. Air Routes
Map of U. S. Landing Fields
Aircraft in Commerce and many other Interesting Facts.

Handsomely Bound in Cloth

THIS EDITION IS ALMOST EXHAUSTED—SEND $2.25 AT ONCE AND THE AIRCRAFT YEAR BOOK WILL BE SENT TO YOU POST PAID — ADDRESS

THE GARDNER, MOFFAT CO.
HARTFORD BUILDING — UNION SQUARE
22 EAST SEVENTEENTH STREET NEW YORK CITY

L. D. GARDNER, PRESIDENT AND EDITOR
W. D. MOFFAT, VICE-PRESIDENT
W. I. SEAMAN, TREASURER
H. M. WILLIAMS, GENERAL MANAGER

AVIATION AND AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN, TECHNICAL EDITOR
LADISLAS D'ORCY, ASSOCIATE EDITOR
GEORGE NEWBOLD, BUSINESS MANAGER

Vol. IX September 15, 1920 No. 4

The spanning of the American continent by the extension of the New York-Omaha air mail route to San Francisco may truly be said to mark the commencement of a new era in the rapid transportation of mails. By this service the air mail will daily advance 400 lb. of mail 42 hr. into San Francisco, which performance cuts the train time between the Atlantic and the Pacific coasts nearly in half. At the same time 1,000 lb. of mail will be accelerated 24 hr. into San Francisco.

The economic results this event is bound to produce are obvious. By speeding up business correspondence, the coast-to-coast air mail service indirectly accelerates production and so contributes to the welfare of the nation.

This result alone would fully justify the expense involved in the establishment of the transcontinental air mail service. But it has still another significance, perhaps more important than the first named.

The 2,650-mile airway which now stretches from New York to San Francisco constitutes probably the greatest system of regularly maintained airports in the world. Fourteen landing fields, completely equipped with hangars, fuel and repair facilities, and situated approximately every 200 miles along the airway, will enable the mail pilots to wing their way on schedule from coast to coast. In addition the ground organization includes a series of radio stations from which weather forecastings will be sent to the mail planes through wireless telephone. As a further safety feature most of the communities situated five miles north and five miles south of the transcontinental airway have agreed to paint in 4-foot letter the names of the cities on the roof of some prominent building for the guidance of all pilots.

The Atlantic and the Pacific Coasts are thus connected by an airway ten miles broad which affords the ground organization that aerial navigation demands. In time of war this airway would enable our service squadrons to be despatched to either coast under the best possible conditions. For commercial purposes its importance promises to become just as great. In fact, the performance of the air mail will undoubtedly act as an incentive to prospective air transport firms by suggesting that if airplanes can carry mail on schedule from coast to coast they can likewise transport passengers.

The Air Mail Service is to be congratulated upon the way in which it has forged its way westward. Progressing step by step, it overcame obstacles that seemed well nigh unsurmountable a few years ago, until it succeeded in completing the aerial link between the Atlantic and the Pacific coasts.

Nomenclature for Aeronautics

The importance of a standard nomenclature for aeronautics is obvious at first sight. In the early days of aviation there existed a considerable chaos in the matter of aeronautical terms, many investigators coining their own words, others using French terms none of which were in general clearly defined. The term *decalage*, which has indifferently been used to denote difference in incidence between the upper and lower plane of a machine and difference in incidence between the main planes and the tail plane, whereas in French it is mainly employed for expressing stagger, is a classic instance.

The issuance, by the National Advisory Committee for Aeronautics, of a new and greatly enlarged nomenclature for aeronautics will therefore be warmly welcomed by the aviation world. While few changes occur in the new compilation in comparison with a previous report, the work at hand (Report No. 91) contains a great number of additional terms which the practice has confirmed in their usage. The whole compilation strikes us as being very carefully thought out, with the definitions thoroughly clear and precise. The introduction of the term *cell*, to denote "the entire structure of the wings and wing trussing on one side of the fuselage of an airplane, or between fuselages and nacelles, where there are more than one," is a happy adaptation of the French *cellule* which will fill a long felt want.

In view of the important position the National Advisory Committee for Aeronautics holds in the aviation world it is to be hoped that its new nomenclature will find a widespread use not only by aeronautical writers, but also by the lay press, which is altogether too prone to use misnomers in subjects aeronautical. The worst and most commonly committed offense in this respect is the use of the term *airship*—which denotes a dirigible balloon only—for *aircraft*, that is any kind of aerial vehicle, be it balloon, airplane or parachute. A concerted action by the American press with a view to teaching the public—and their own writers—correct aeronautical terms would do much good in overcoming this regrettable state of affairs.

Air Cooled Aero Engines

The water-cooled engine has almost monopolized the attention of American manufacturers to the exclusion of air-cooling. Many advantages over the latter have been claimed and advanced as the reasons for this state of affairs, which reflects their relative popularity for automobiles. Chief among them were greater reliability, economy, and less limitation of size of cylinder. On the other hand, lighter weight was generally conceded to the air-cooled engines. Scientific research has changed some of these arguments. It is now possible to get thermal efficiencies with air cooling quite as good, if not better, than in water-cooled engines. The construction of the fixed cylinder radials is simpler, if anything, largely on account of the elimination of the water pumps. Reliability should therefore be better. Great progress in the power per cylinder and total power has also been made. The overall diameter of the larger motors is excessive from the resistance point of view, but there is reason to believe that research can solve this problem of keeping the head resistance within reasonable limits. All of these points hold so much promise that it is pleasant to behold the interest and support of this type shown by Army and Navy.

The Design of Monocoque Fuselages

By Armin Elmendorf, M. Sc., M. E.

Consulting Engineer, Haskelite Mfg Co., Chicago

In airplane evolutions involving turning about a horizontal lateral axis the flexure stresses are a maximum in the upper and lower surfaces of the fuselage and the shear stresses are a maximum along the neutral or mid section where the flexural stresses are zero In turns to the right or left the flexural stresses are greatest along the section dividing the fuselage into a right and left half The ratio of the maximum flexural stresses developed on top and on bottom of the fuselage to the maximum flexural stresses developed at any time in the sides is variable and unknown, but the stresses due to turning about a horizontal axis as for example, when coming out of a dive, are here considered as being very much higher than those due to lateral turns.

Upon analyzing the forces acting on a fuselage undergoing rotation in the air about a horizontal axis, it will be seen that the fuselage may be treated as a cantilever beam. The internal or resisting moment of the stresses induced in the fuselage at any section distant X from the resultant vertical force on the tail surfaces is equal to the moment of the resultant vertical pressure about a horizontal axis in the section under consideration The distribution of stresses under these conditions is shown diagrammatically in Fig 1, the stresses above the neutral plane AB being tensile and those below compressive Up to the elastic limit of the material, the stresses vary in magnitude directly as the distance above or below the neutral plane.

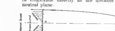


FIG. 1. DIAGRAMMATIC REAR SECTION OF FUSELAGE SHOWING FORCES ACTING UPON IT IN A VERTICAL DIRECTION AND THE RESULTANT STRESSES

The present discussion is limited to the true monocoque fuselage in which no longitudinal reinforcing is used All the stresses, both flexural and shear, are therefore carried by the fuselage shell.

The shear strength of plywood of which the fuselage is assumed to be made is so high that no attention is here given to the sheer stresses in the fuselage.

The tensile strength of wood parallel to the grain is somewhat superior to the compressive strength in the same direction, so that failure due to tension would hardly be expected in a symmetrical section of a fuselage properly strengthened at the cut-outs. For this reason the discussion may be limited to an analysis of the stresses existing on the compression side of a fuselage. Tests on fuselages of both true monocoque and semi-monocoque design have shown, however, that failure does not take place in compression either, until *after collapse due to buckling* The engineer must therefore design the monocoque fuselage so as to get maximum buckling strength

Proper Direction of Grain of Face Veneer

Fig 2 shows an element or section of the fuselage taken from the compression side The external forces acting on this element are the end stresses or pressures tending to cause the element to collapse as a column and the side forces (either tensile or compressive stresses) tending to prevent the collapse of the column. Besides the latter forces there is another system of forces that resists collapse, namely, that composed of the internal or fiber stresses within the element itself

The resisting stresses tending to prevent buckling will be spoken of as the longitudinal stresses, and the transverse stresses, the former being the fiber stresses within the column strip in the direction of the longitudinal elements of the fuselage. If now the plies of the fuselage shell are so proportioned as to get the greatest stiffness longitudinally, the assistance rendered in the transverse direction to prevent buckling will be small, and if the construction is such that greater stiffness is in the transverse direction, than the assistance in the longitudinal direction is reduced There is this difference in the two groups of stresses, however the longitudinal stresses are the result of a direct compression force and an eccentricity of this force causing bending In the transverse direction the direct compression force is absent and the resisting stresses exist only when slight buckling or lateral displacement has taken place

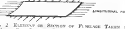


FIG 2 ELEMENT OR SECTION OF FUSELAGE TAKEN FROM UNDER SIDE SHOWING LONGITUDINAL STRESSES TENDING TO CAUSE BUCKLING (HERE INWARD) AND THE TRANSVERSE STRESSES TENDING TO PREVENT BUCKLING

While it seems reasonable to believe that the greatest reinforcement is received longitudinally, assuming equal moduli of elasticity in the two directions, no mathematical expression can be given for this relation Tests must therefore be relied upon to determine the direction in which greatest stiffness should exist so as to obtain maximum resistance to buckling.

Tests made at the Forest Products Laboratory on three-ply plywood, in which all plies are of the same thickness and species, showed that the modulus of elasticity (stiffness) of such material is from ten to fourteen times as great parallel to the face grain as across the face grain. Material of this kind was used in tests made at the Haskelite Research Laboratory to determine the maximum resistance to buckling of sections of plywood having curvatures such as exist in fuselages of the monocoque type. Three-ply red gum plywood made of 1/20 in veneer were selected The test specimen and method of testing are illustrated in Fig 3 It is apparent from the results of the tests given in Table I, that decidedly superior results were obtained in all cases by loading in a direction parallel to the face grain. From these tests the conclusion is drawn that when all plies are of the same thickness and species, greater resistance to buckling is obtained in a monocoque fuselage when the face grain extends in the longitudinal direction

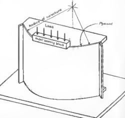


FIG 3. METHOD OF TESTING RELATIVE RESISTANCE TO BUCKLING OF PLYWOOD WHEN THE GRAIN OF THE FACES EXTENDS LONGITUDINALLY WITH THE ELEMENTS OF THE FUSELAGE AND IN THE TRANSVERSE DIRECTION

TABLE I
BUCKLING LOADS IN LB OBTAINED IN TESTS

	Radius 8 in		Radius 14 in		Radius 20 in	
	Long Grain	Transv Grain	Long Grain	Transv Grain	Long Grain	Transv Grain
	2840	2010	2300	1500	2300	1100
	3070	1810	2600	1660	2100	1080
	2770	1830	2540	1280	2050	1000
		1830		1873		1020
Av	2890	1880	2280	1470	2150	1040
Long grain over transv	53 per ct		55 per ct		106 per ct	

It is sometimes suggested that superior results may be obtained in plywood if the grain of successive plies cross at angles other than 90 deg, as for example, at 45 deg or 60 deg Such constructions are, however, not to be recommended for flat panels or where the curvature is low Tests have shown that a deviation even as small as 10 deg from the common 90 deg. angle between the grain of successive plies may introduce serious warping In addition to the fact that the resistance to buckling may be lowered, it is undesirable to use odd angles between the grain of successive plies in the fuselage.

The rule for symmetrical construction should be adhered to unless the curvature is sufficiently high so that the tendency to warp is largely counteracted by the bend. Symmetrical construction in plywood is obtained by the use of an odd number of plies so arranged that for any ply on one side of the core there is another ply on the opposite side of the same thickness, species and distance away from the core The grain of successive plies should cross as nearly at right angles as feasible Under these conditions the grain of symmetrical plies all runs in the same direction

Number of Plies

Column tests on plywood panels show that there is a decrease of the column strength parallel to the face grain and an increase in strength in a direction at right angles to the face with an increase in the number of plies for a given panel it follows that the three-ply construction is preferable to the thickness Inasmuch as increasing the number of plies reduces the stiffness longitudinally when the face grain is longitudinal, it follows that the three-ply construction is probably preferable to the five-ply construction. Most fuselage shells are so light, moreover, that the use of more than three plies for a given shell thickness necessitates the gluing of very thin veneer which may be impracticable.

The cost of the five-ply shell is also considerably greater than the three-ply shell, and its weight for a given thickness is slightly greater on account of the added glue.

Species

Maximum column load (and buckling strength) varies directly as the modulus of elasticity of the column material and as the cube of the thickness The first criterion suggests the use of high density woods, such as yellow birch, sugar maple and beech, because the modulus of elasticity is greatest for such high density species, the second factor points to the use of low density woods such as basswood, white pine, redwood, Spanish cedar, spruce and yellow poplar, for the latter give greater thickness per unit weight Since the desideratum is high specific column strength, it is necessary to combine modulus of elasticity and thickness when making a comparison. The veneer species given above are all satisfactory for airplane plywood Plywood made of them will be grouped into two groups—high density and low density plywood. In the form of glued three-ply wood, ranging in thickness from 0.1 to 0.5 in, the average specific gravity of the former is about 0.67, based upon oven dry weight and air-dry volume, and the average specific gravity of the latter about 0.43

In the following discussion the subscript (2) refers to low density plywood and (1) to high density plywood. P is the maximum load, E the modulus of elasticity, t the thickness of the column section, and g the specific gravity The following relation holds for long columns, irrespective of the condition of the ends, as long as the latter are the same for any two columns compared.

$$\frac{P_2}{P_1} = \frac{E_2 t_2^3}{E_1 t_1^3} \qquad \text{(1)}$$

It is desired to know what the ratio of the maximum loads is for two columns, one of low and the other of high density plywood, when the weight of the two columns is the same. Since the thickness is inversely proportional to the density, equation (1) may be written

$$\frac{P_2}{P_1} = \frac{E_2 g_1^3}{E_1 g_2^3}$$

Comparing three-ply redwood with three-ply yellow birch as an example by substituting the respective values of the moduli of elasticity and the specific gravities, the following is obtained:

$$\frac{P_2}{P_1} = \frac{1180000}{2260000} \times \frac{67^3}{42^3} = 2.12$$

In other words, a column of three-ply redwood of the same weight as a column of three-ply birch should sustain slightly more than twice the load of the latter

In Table II, under "Computed Ratios," the ratios of column strengths for a number of high and low density species are given

Under "Ratios from Column Tests," comparisons are made between the actual loads sustained under test by round-ended columns, 12 in. long, of each of the species under consideration, the exact unit column load for a particular thickness being obtained from curves plotted from test data between maximum unit column load and column thickness. The thickness of the high density column was assumed given (the two thicknesses used were 0.15 in and 0.25 in), and the thickness of the low density column was computed from this by means of the average specific gravity data. The unit load corresponding to the thickness obtained in this way determined the total load so that the ratio division could be made, since the load of the high density columns was known. From the data given in Table II, it will therefore be seen that a low density column of any of the species listed, of the same weight as a high density column, should sustain from 2 to 2.5 times the load of the latter, consequently the resistance to buckling is greater for low density than for high density plywood of the same weight

Another important factor commends the use of low density wood for use in fuselage shell construction, namely, its superior resistance to conditions tending to warp plywood Low density plywood is appreciably thicker than the high density plywood of the same weight, consequently it tends to remain "put" better than the latter, for warping decreases with an increase in thickness Warping also appears, in general, to be less for the low density plywoods, even when of the same thickness as the high density plywoods.

Fuselage Section

Having decided upon the species and construction of the plywood itself, the designer is confronted with the selection of the most effective fuselage section In the following discussion, it will be assumed that the aerodynamic characteristics of a fuselage are not materially altered by changing the transverse section, and that the mechanism and apparatus the fuselage houses are equally readily accommodated in each of the various sections considered

Previous discussion brought out the fact that buckling in a fuselage shell is due to a form of local column failure. The fact that failure due to buckling of the shell may in most designs be expected before failure due to compression or tension occurs was also brought out.

In Fig 4, four arcs of assumed fuselage sections are shown each 6 in. long and 0.06 in thick If these arcs are on the lower or upper surface of the fuselage, the strips of which they are the sections will be subjected to end forces when the fuselage is stressed, and they will act as columns reinforced along the edges when buckling takes place. The ratio of strengths of columns having sections similar to those shown depends upon the length of the arc chosen and the thickness of the section, as well as upon the support along the edges.

Proportionality between column strength and minimum moment of inertia about an axis through the center of gravity of the section will be assumed because such a relation holds

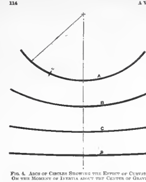


FIG. 4. ARCS OF CIRCLES SHOWING THE EFFECT OF CURVATURE ON THE MOMENT OF INERTIA ABOUT THE CENTER OF GRAVITY.

R = Ratio of I_{cg} of any section to I_{cg} for section B
S = Length of arc = 6 inches for all arcs
r = Radius in inches
I_{cg} = Moment of inertia about hor axis through center of gravity of the arc
t = Thickness of arc in inches

$$r = KS$$

$$t = \frac{S}{100}$$

Curve	K	R
A	½	3.58
B	1	1.00
C	2	0.12
D	3	0.02

exactly for ordinary long columns. In order to compare the strengths of columns having the different sections shown in Fig 4, it is then simply necessary to compare their moments of inertia about a horizontal axis through the center of gravity.

The rapid change in moment of inertia for the various sections shown in Fig. 4 is very significant in that it shows approximately what effect increasing curvature may have on the resistance to buckling. Section B, for example, has a moment of inertia about a horizontal axis through its center of gravity that is fifty times as great as that of section D. It is obvious that a change in curvature from section D to that of section B should result in a very marked improvement in resistance to buckling. That sharper curvatures give greater resistance to buckling is borne out by the tests, as will be seen from the results in Table I.

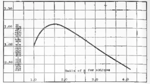


FIG. 5 COMPARISON OF SECTION MODULI OF ELLIPSE AND CIRCLES

Minor axis b of ellipse constant = 1.0
Major axis a of ellipse variable
Section moduli taken about the minor axis
Perimeter of ellipse = circumference of circle
t = thickness of shell; st = 0.1 for all sections

Assuming the same fiber stress, it remains to be seen which type of complete section gives the greater resisting moment for a given weight. A comparison of strength is here made between fuselage shells having an elliptical section and those having a circular section. For this purpose an elliptical section having a minor axis of fixed length was assumed and the ratio of the length of the major axis to the minor axis was varied, keeping the area of the section of the shell (i. e. the weight of the fuselage) constant in each case. Circular sections corresponding to each of the elliptic sections were determined such that the circumference of the circle is equal to the perimeter of the corresponding ellipse and the thickness of the circular shell is equal to the thickness of the elliptic shell. Moments of inertia about the minor axis were computed in each case and the section moduli determined for each. The same was done for the circular sections. The results of these computations are given in Fig. 5, in which the ratio of the section modulus of the elliptic sections to the section modulus of the circular section is plotted against the ratio of the major to the minor axis of the ellipse. Since the external bending moment a fuselage sustains for a given stress is directly proportional to the section modulus, the fuselage section having the greatest section modulus will sustain the greatest bending moment. On the basis of their section moduli, Fig. 5 shows that for ratios of major and minor axis from 1 to about 3, the elliptic section has a slight advantage over the circular section. Add to this the very significant advantage of greater resistance to buckling on account of the sharper curvature at the points most highly stressed, it will be seen that the elliptic section should show appreciably superior strength over the circular section.

The elliptic section also provides greater depth for the pilot or passenger.

TABLE II
COMPARISON OF MAXIMUM LOADS SUSTAINED BY LOW AND HIGH DENSITY THREE-PLY PLYWOOD COLUMNS, ALL OF THE SAME WEIGHT
Ratio of Maximum Load of Low Density Three-Ply Plywood Column to High Density Three-Ply Column of the same Weight.

	BIRCH			BEECH			SUGAR MAPLE		
	Ratio from Column Tests		Computed Ratio Any Thickness	Ratio from Column Tests		Computed Ratio any Thickness	Ratio from Column Tests		Computed Ratio Any Thickness
Low Density Species	Thickness of Birch Column 0.15"	Thickness of Birch Column 0.25"	$\frac{E_2\,g_2^3}{E_1\,g_1^3}$	Thickness of Beech Column 0.15"	Thickness of Beech Column 0.25"	$\frac{E_2\,g_2^3}{E_1\,g_1^3}$	Thickness of Maple Column 0.15"	Thickness of Maple Column 0.25"	$\frac{E_2\,g_2^3}{E_1\,g_1^3}$
Redwood	3.32	2.34	3.12	2.41	2.51	2.22	2.43	3.01	2.57
Spruce	2.48	1.93	2.34	2.31	2.03	2.40	2.32	3.00	2.51
Yellow Poplar	1.64	1.72	1.64	1.71	1.84	1.73	1.78	1.88	1.86
Spanish Cedar	3.12	3.10	1.98	2.20	2.31	2.00	2.26	2.48	2.22
Basswood	2.37	2.28	2.17	2.46	3.19	2.28	2.62	2.41	2.44
Av Ratio of strength of low density columns to high density columns of the same weight	3.17	2.32	2.05	2.38	2.37	2.18	2.88	2.51	2.68

Aeromarine Model 40 Hull Test

The tests were made in accordance with instructions received from the Bureau of Construction and Repair and are inserted in the appendix of this report.

To simulate flying condition the hull was suspended by means of the flying wires attached to the hull and the whole arrangement constructed so that the hull would be balanced at the center of pressure for low speed.

In making the test for diving condition the hull was suspended in the same manner and the tail surfaces were loaded twenty pounds per square foot, the part of the hull aft of the rear flying wires acting as a cantilever.

The test for landing load was made with the hull supported on a small handling truck, and loads added in increments of a unit landing load.

Data and Place

The tests were made at the Aeromarine Plane and Motor Company's factory, Keyport, New Jersey. Mr Fred Keller of the Engineering Department of the Company was in charge of the tests. Ensign Edmund A. Whiting, U. S. N. R. F., represented Lieutenant A. Bledsoe, Inspector of Naval Aircraft, U. S. N.

Mr. R. B. Beisel of the Bureau of Construction and Repair was present at the first two tests. The tests were made on the following dates:

I. Flying Condition—July 10, 1919.
II. Diving Condition—July 10, 1919.
III. Landing Condition—July 11, 1919.

Procedure

Test No. 1, Flying Condition.—Hull was suspended from staging by means of the inner lift cables, and simulated flight condition to be at low speed with the center of pressure at 28 per cent aft of the leading edge of the mean wing chord. The unit loads were comprised of the weights of the following parts. Bare hull, fuel, pilot, passenger, controls, instruments, etc. A tail load was used to balance the machine and introduce a tension in the lift wires corresponding to the center of pressure location specified. The loads were applied by means of sand bags and distributed over the hull simulating as nearly as possible the distributed hull weight. The hull in this condition was tested to a factor of safety of six.

Test No 2, Diving Condition.—For this test the hull aft of the step was loaded as a cantilever with a load of 20 pounds per square foot on the tail surfaces. The same set up was used as in Test No 1. The hull was kept in balance with center of pressure at 28 per cent of chord by loading the fore part of hull. The hull successfully carried a load of 20 pounds per square foot, on the tail surfaces, acting as a cantilever.

Test No 3, Landing Condition.—The hull was supported on a cushioned landing truck, the size of the truck simulating the position the hull takes at the beginning of a step landing. The engine section was included in the set up. The load imposed included all the weights not contained in the hull and tail, i. e. wings, wing floats, engine, oil, tanks, radiator and water, etc. The load was carried by the engine section truss-sing. The structure was loaded as follows:

A factor of safety of twelve for load representing the wings, wing floats, etc. A factor of safety of ten for load representing the engine, oil, tanks, radiator and water, etc. A factor of safety of ten for loading representing one quarter the weight of the upper wings, motor, etc., acting in a horizontal direction and assumed as a thrust.

Results

In tests Nos. 1 and 2, the loads were applied until a factor of safety of six was obtained. The hull successfully stood the test.

In test No. 3, a factor of safety of ten was attained for all parts. At this point it was not possible to continue adding the horizontal load and the engine loads. The loading, however, was added to the engine section panel until a factor of safety of twelve was obtained without sign of failure.

Construction of Hull

The detailed construction of the Aeromarine Model 40 Flying Boat hull shows no radical departure from the current practice.

The hull consists of built-up transverse frames of spruce sawed to shape with the bottom ribs extending past the side ribs, the ends of which are held to the side ribs by one-half inch to three-quarter inch struts. This extension forms the fins on the forward part of the boat. All frame joints are joined with glue and held in place by 2 plywood gussets on each side of a frame at each corner, riveted with copper rivets and burrs. The longitudinal frame consists of ash chines rabitted to receive the planking, spruce deck clamps of the same type, ash or oak forward keel and keelson, spruce after keelson with two auxiliary keelsons or stringers equally separated. The chines and deck clamps overlap at the step station and are well riveted to take the stress at this point. The sides and top are planked with three ply birch and poplar veneer, fastened with brass screws. The bottom is planked with twoskins, built up of Port Orford cedar with an inner layer of cotton fabric with marine glue and quilted with bifurcated brass rivets. The landing strains are taken by two heavy spruce thrust braces leading from the forward wing beam to the bottom of the hull structure.

The hull has four water tight bulkheads with drain plugs readily accessible and one strengthening bulkhead. The cockpit provides for two people and the control bridge, instrument board, Pyrene, foot bars and Porta Phone are located in this section. The seats are built into the hull and large comfortable cushions are fastened to the seats. Two Simmons Type No. 1 safety belts are provided for the pilots. The main gasoline tank is located just aft of the bulkhead at the forward wing beam.

Flying Condition Test

The hull was suspended from suitable staging by means of the inner lift cables. The upper part of the staging to which

SET-UP FOR FLYING CONDITION TEST

SET-UP FOR DIVING CONDITION TEST

these cables were attached was mounted on steel rollers, enabling the hull to be kept balanced with the point of support at the center of pressure for low speed.

The load was made up of the following weights:

Hull	430 0
Foot Bar	8 4
Instrument Board	17 0
Pump	2 8
Control Bridge	24 0
Tachometer Drive	7.5
Pilots and Seat	387 8
Throttle	1 8
Ports Phone	2.9
Gas and Tank	182 8
Anemometer Pump	5.5
Gas Gauge	3.8
Control Wires	8 0
Tail Unit, including Elevator Tail Plane Rudder and Fin	87 0
TOTAL	1137.3 lb

The weight of the hull itself, (430 lb.) was distributed by computing a weight per unit volume. The total volume of the hull was found by using Simpson's rule for volume.

$V = 1/3\, s\, (a + 4b + 2c + 4d + \qquad 2x + 4y + z)$

s = Distance between stations.

$a\ b\ c$ = Areas or ordinates at respective stations.

It is necesary to have an odd number of stations.

The volume computed by using this formula gave 192.2 cu. ft.

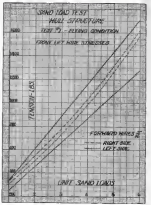
In computing the volume used to determine the weight distribution, nine stations were taken and the area at each station determined. The average area for two adjacent stations, times the distance between them, (3 2 ft.) gives the average volume. In comparing the sum of these with the volume obtained by using Simpson's rule, a difference of 3 per cent was found. Each average volume times weight per unit volume gives the weight of that section of the hull which was used as the unit load for that section of the hull.

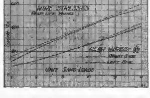
The table below gives the various weights of the parts and a summary of the loads used in the test, together with the extra load on the tail to balance the hull at the required center of pressure.

The loading was done by means of sand bags placed to simulate the weight of the various parts.

Each load was equal to a unit flying load. The loads were applied until a factor of safety of six was obtained.

There was no sign of failure in any part after load had been removed, except the following one item. The tubular brace which runs from the middle of the rear seat rail down to the after side of the floor member No. 6 bent near the floor. The tube is flattened at this point to fit onto the floor and take the bolts. When the tube bent, the rear seat rail took the six loads with considerable deflection, but no failure. In future hulls, this tubular strut will be fastened to the forward side of the floor which will give support to the flattened section and relieve this trouble. The sand load representing the weight of passengers received no support from the back of the seat for this was not installed. Furthermore the c. g. of this load was no doubt somewhat back of the c. g. of the passengers for the very high pile of bags sloped aft somewhat.





A small load was placed on the forward part of the platform in order to balance the hull in the proper position.

The hull was inclined 6 deg from the horizontal, bow end up to allow for angle of lift wire to vertical to fore and aft center line of hull, due to the 6 in. stagger

Readings were taken for the stress in the supporting wires for each unit load. A Larson Tensionmeter was used for this.

Cantilever Test

During the test under flying condition the tail load did not reach a value corresponding to 20 lb per sq ft. The same set-up was used as in the test under flying conditions. A platform was arranged so that the tail surfaces could be loaded.

The following loads were applied:

Tail plane—Area 39 sq. ft

Total load—$39 \times 20 = 780$ lb

As the front and rear tail plane beams each take half the load, the load applied to each beam would equal $\frac{780}{2} = 390$ lb. due to load on tail plane.

Elevators (2) area 25 6 sq ft.

$25\,6 \times 20 = 512$ lb

This load is carried by the rear beam of the tail plane, the load being as follows:

Front Beam	390 lb.
Rear Beam	902 lb.
Total	1292 lb.

The above load (1292 lb) was applied in five unit loads.

Considerable load was applied to the forward part of the hull in order to keep the hull balanced at the required center of pressure.

No part of the hull showed any sign of failure when the load was equal to 20 lb per sq ft. or a factor of safety of six

The total load on the tail surfaces and the hull, loaded as a cantilever, aft of the rear inner lift wires, was 1292 lb

Landing Condition

The hull was mounted on a cushioned handling truck, the size being such as to simulate the position of the hull taken at a step landing. The engine section trussing was included in the set up. The hull was set up with the engine bed horizontal The entire load was carried by the engine section bracing and transferred through them to the bulkhead in the hull A load simulating the forward tendency in landing, due to inertia, was assumed as one quarter the engine and wing load, less lower wing, and was applied at the engine bearers.

Computation of Loads—The load imposed on the engine section was composed of the following weights.

Motor			418 0 lb
Propeller			28 0
Water			26 8
Oil			18 0
Gravity tank	6		
Gas in gravity tank	30		36 0
Radiator and brackets			51 0
Motor Beds			25 0
Lower forward engine section struts		16 62	
Lower rear engine section struts		16 62	
Lower side diag engine section struts		13 75	
		½ X 46 99	
		23.46	23.46
Upper side diag engine section struts		6.0	
Upper front vert. engine section struts		6 12	
Upper rear vert. engine section struts		6 12	
		18.24	18.24
Starting Crank			7 0
Radiator and pipes (2)			4 25
Streamlines			2 25
			669.2 lb

The load imposed on the engine section in landing, due to the weight of the wing structure is as follows

The data used is taken from the stress analysis made by Ensign Mellen of the Bureau of Construction and Repair

Total vertical reactions at points of attachment of wings

Upper R_1 = —80 0 out board

R_2 = —62.4

R_3 = —99 2

R_4 = —32.4 inboard

Lower R_1 = —85 6 outboard

R_2 = —79 6 outboard

R_3 = —25 8 inner lower section of spar

—465 0 lb

All the loads due to these reactions are taken by the upper engine section panel with the exception of that taken by the inner lower section of spar, or 25 8/465 = 5 55 per cent

5.55 per cent of the weight of the wings is to be applied at the sidewalk.

604 lb. equals weight of wings, including wing tip floats.

$604 \times 5.55 = 33.5$ lb applied on sidewalks.

Therefore, the load to be applied to the upper engine section panel is equal to 100 — 5 55 = 94.45 per cent.

94 45 per cent $\times$ 604 = 570 5 lb equal to the load to be applied to the engine section panels, due to wings. To this is added the weight of engine section which is 25 lb., making the total unit load for this platform = 595.5 lb

Set-up for Landing Condition Test

Load on hull due to one-half weight of struts, which are below engine bearers = ½ × (16 62 + 16.62 + 13.75) = 23 46 lb The engine bearers were alloted the other one-half of this load in order to approximate the condition that struts support themselves

Horizontal Load—The load, simulating the forward tendency in landing, due to inertia, was considered to equal one-fourth the weight of the upper wing, engine load, and the proportional part by the wing area of the weight of interplane struts and wires. This load was applied to the rear part of the engine bearers by using tackle

Weight of Upper Wing	230 0
Weight of Wires	41 7
Weight of Struts	49 0
Area of Upper Wing	291 sq. ft

The amount of the weight of struts and wires taken by the upper wing is $291/491 \times 90\,75 = 53\,8$ lb

$230 + 53\,8 = 283\,8$ lb carried by upper wing

Wing Load = 283 8

Engine load = 669 2

Total static load = 953 lb

953/4 = 238 2 lb. is the load acting in a horizontal direction, due to inertia.

Procedure

The loading was applied in units of a single landing load and continued until a factor of safety of ten was obtained. At this point difficulty was experienced in applying further loads to the engine section. However, the loading was continued on the engine section panel until a factor of twelve was obtained The factors of safety represented by the amount of load carried by each unit is as follows

Engine Section Panel—Factor of Safety	12.
Engine Bearers—Factor of Safety	10.
Horizontal Load—Factor of Safety	10.

Summary Loading

Load	A	B	C	D	E	F	G	H	J	K	L	M	N
1	0	0	0	0	8	0	0	8	70.5	19 8	388	134	8
2	40	38 8	88	86.5	61	32	15 5	8.5	97	88.2	398	134	6
3	40	52 8	88	98 8	61	32	15.5	8.5	127	52 2	398	134	8
4	40	67.5	88	96.5	61	32	15 5	8.5	187	52 8	398	134	8
5	40	88 8	88	96 8	61	32	15 5	8.5	117	52.2	398	134	8
6	40	82 8	88	98 8	31	32	15.5	8.5	127	52 2	398	134	8
Total	200	418 8	440	483.5	305	160	77.5	27 8	768.5	280 8	2378	804	83

Grand Total — 6369 8 lbs.

NOTE

The sum of the loads given in items "A" to "H" inclusive, is equal to the weight of the bare hull

The figure indicates how this load was distributed

The items K, L, M, N, are the weights of controls, personnel, fuel, wires, and tail surfaces

The load given for the tail surface "J" included the amount of load to balance the machine at the required center of pressure.

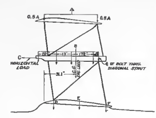
The load given for the tail surface "J" included the tail bar, control bridge, stabilizer, and fin, but no elevators or rudder

Hull and foot bar, control bridge, stabilizer, and fin, but no elevators or rudder

The first load brought the hull up to its flying condition.

MODEL 40 FLYING BOAT

Flying and Diving Load Distribution



Load	A	B	C	D	E	F	Load
			Summary of Loading				
1	595.5	669.2	233.2	12	23.5	12	1
2	595.5	669.2	233.2	12	23.5	12	2
3	595.5	669.2	233.2	12	23.5	12	3
4	595.5	669.2	233.2	12	23.5	12	4
5	595.5	669.2	233.2	12	23.5	12	5
6	595.5	669.2	233.2	12	23.5	12	6
7	595.5	669.2	233.2	12	23.5	12	7
8	595.5	669.2	233.2	12	23.5	12	8
9	595.5	669.2	233.2	12	23.5	12	9
10	595.5	669.2	233.2	12	23.5	12	10
11	595.5						11
12	595.5						12
Sub Total	7146.0	6699.0	2332.0	120	235	120	Sub Total

Total—16,695 lbs.

Note
"E" was equally divided between right and left sidewalks.
Platforms were placed so that "C G" of load would be coincident with "C G" of parts which load represented

LANDING LOAD MODEL 40 FLYING BOAT

The weights of the engine beds, engine section struts, and panel were neglected in the first load and were not subtracted from the unit load to give first unit load.

The hull successfully withstood the above loading and no signs of failure developed After the load was removed all parts were carefully examined for signs of failure.

No failure developed under this test.

The hull was loaded to a factor of safety of ten plus, further loading could not be made without difficulty.

Some difficulty was experienced with the persistent stretching of ropes supporting horizontal load. It was necessary to remove the horizontal load on the platform during the test and shorten the rope

Appendix

Procedure to be adopted in Sand Load Test on Aeromarine 40 Hull—The hull of the Aeromarine Model 40 boat seaplane is to be tested for

I Flying Condition.
II. Diving Condition.
III. Landing Condition.

The procedure to be adopted is:

I. *Flying Condition* —Suspend the hull from a suitable frame work by means of the inner lift cables. Consider the flight condition to be low speed with the C P at 28 per cent aft of the leading edge of the mean wing chord. The loads which are to be considered are bare hull, fuel, pilot and passenger, miscellaneous as instruments, etc, and tail load. The tail load will be used to balance the machine and introduce a tension in the lift wires corresponding to the C P. location specified. The concentrated and tail loads will be represented by sand bags and the hull load will be distributed over the structure by means of the sand bags simulating as nearly as possible the distributed hull weight. The hull should be tested to a load corresponding to a factor of safety of 6, but not final destruction Tensionmeters will be used to determine the load taken by the lift cables.

II *Diving Condition* —After completion of the flying condition of testing and provided the tail load in I has not reached a value corresponding to 20 lb per sq ft. on the elevator and tail plane, the hull aft of the step shall be loaded as a cantilever for the load of 20 lb per sq ft.

The set up used in I is to be used

The load is to be placed to simulate an equivalent load on the elevator and tail plane. The fore part of the hull is to be balanced so as to equalize the load on the flying wires.

III. *Landing Condition*—The hull is to be mounted on a suitable cushioned framework The size of the framework and the part of the hull which is to rest on same is to be such that it will simulate the position the hull takes at the beginning of a step landing It is possible that this condition will be realized when the hull is resting on the handling truck. The engine section trussing is to be included in the set up The load imposed is to include all the weights not included in the hull and tail as wings, wing floats, engine, oil and tanks, radiator and water, etc. This load is to be carried by the center engine section trussing and is to be simulated by means of sand bags placed to properly represent the load imposed. The structure is to be loaded to destruction by increments representing a unit landing load.

N. A. C. A. Reports

Nomenclature for Aeronautics. Synopsis of Report No. 91, National Advisory Committee for Aeronautics.

This nomenclature and list of symbols were approved by the Executive Committee of the National Advisory Committee for Aeronautics, for publication as a technical report on April 1, 1920, on recommendation of the Subcommittee on Aerodynamics.

The purposes of the Committee in the preparation and publication of this report is to secure uniformity in the official documents of the Government and, as far as possible, in technical and other commercial publications. This report supersedes all previous publications of the Committee on this subject.

The Subcommittee on Aerodynamics had charge of the preparation of the report. It was materially assisted by the Interdepartmental Conference on Aeronautical Nomenclature and Symbols, organized by the Executive Committee, with the approval of the War and Navy Departments, for the purpose of giving adequate representation to the divisions of the Army Air Service and to the Bureaus of the Navy Department most concerned. The first meeting of the interdepartmental conference was held on October 23, 1919, and the second meeting on January 15, 1920, at which meeting this report was unanimously approved and recommended to the Subcommittee on Aerodynamics, with the reservation that stability terms and power-plant terms be given further and special consideration.

The stability terms were accordingly referred for special consideration to Messrs. E B Wilson, J C Hunsaker, A F. Zahm, E. P Warner, and H Bateman, and the power-plant terms were referred to the Subcommittee on Power plants for Aircraft The complete report was adopted by the Subcommittee on Aerodynamics on March 8, 1920, and recommended to the Executive Committee for approval and publication

Bomb Trajectories Synopsis of Report No. 79, National Advisory Committee for Aeronautics

This report is a mathematical discussion of the trajectories of bombs or projectiles when account is taken of the resistance of the air. It is impossible to express the motion of the bomb exactly in that it must be approximated between two limiting curves whose equation can be expressed.

It is found that the trajectory in ordinary cases is not far from a parabola and with an initial velocity of 200 ft. per sec. and a terminal velocity of 800 ft. per sec. in a drop of 2,000 ft. the correction can be determined to within 15 ft.

Copies of these reports may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D. C.

The Laird "Swallow"

A consideration of the present cost of operations of commercial aircraft, as well as of the airdrome conditions throughout the country shows that the successful commercial airplane must be one which will have a thoroughly reliable engine with a minimum of upkeep costs.

The plane must have a low landing speed and a quick take-off together with a fast climb. On the other hand, the present demand for cross country travel by air requires that a machine have a good maximum speed.

With these features in view the Laird "Swallow" was designed to meet the requirements of a commercial airplane, being especially adapted to passenger carrying and cross country flying

Main Planes

The R. A. F. No. 15 wing section is employed. The wing chord is 58 in The wings are in four main panels, aside from the center panel, which is 30 in wide Upper and lower panels are interchangeable Gap between wings is 58 in Dihedral angle, upper and lower wings, 1.5 deg

Ribs are built of grooved spruce battens, screwed to basswood webs, which are lightened between spars Internal wiring is with No 10 hard wire.

Best grade of Irish linen is used for wing covering, coated with dope over which are applied two coats of color varnish in any desired color, blue gray being standard finish unless otherwise specified.

Front View of the Swallow

Seating Arrangement

The front cockpit is arranged to accomodate two passengers side by side, and is luxuriously upholstered Carpeted floors and inclined foot rests add much to the comfort of the passengers.

A large windshield of transparent celluloid built up with aluminum framework is attached to the cowling in front of the passenger's cockpit This offers protection from the wind to the pilot as well as to the passengers There is ample room under the passenger's seat to accomodate a large size suit case, and a large tool compartment is provided in the back of the pilot's seat

Landing Chassis

The chassis is the conventional V type. The V's are constructed of steel tubing, spaced at the bottom by two steel tubing tie rods—one in front and rear of the axle. The axle is 1½ in. in diameter, with a 3/16 in. wall The upper ends of the chassis are attached to the fuselage by four bolts running parallel with the longerons. Double cables are used, one set fore and aft

Controls

The pilot's cockpit is fitted with the standard stick control, and all necessary motor controls. On the dashboard in the pilot's cockpit are mounted altimeter, registering up to 15 000 ft., thermometer, oil gauge, motor thermometer, and magneto cut out switch.

Tail Surfaces

Rudder and elevators are unusually large, so that the machine responds quickly to controls at its minimum speed. They are built of steel tubing, all joints being brazed The vertical and horizontal stabilizers are built up similar to the wings, steel tubing being used as entering edge.

Engine

In selecting an engine for a commercial plane the factors to be considered are economy of operation, spare parts available, and last, but not least, an engine that is well known, or in other words, on that the present airplane mechanics are thoroughly familiar with.

On considering these facts it was decided to use the Curtiss OX-5 engine, standard equipment, as it is probably the best known aeronautical engine of today Its known reliability as well as economy in upkeep make it thoroughly adaptable for a commercial airplane

Specifications

Number of Passengers	2
Crew	1
Engine	Curtiss OX-5, 90 hp.
Weight	
Weight Empty	1075 lb
Weight Fully Loaded	1750 lb

Rear View Showing Seating Arrangements and Tail Unit

Loading	
Power loading	19 44 lb. per hp
Wing loading	5.40 lb per sq. ft.
Dimensions	
Span:	
Upper Wing	36 ft
Lower Wing	36 ft
Wing Chord, Both Planes	58 in.
Gap Between Wings	58 in.
Overall Length	23 ft. 4 in.
Overall Height	8 ft. 8 in.
Stagger	10 in.
Wing Areas:	
Upper	168 sq. ft.
Lower	156 sq ft.
Total with Ailerons	324 sq ft.

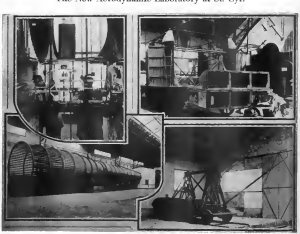
Useful Load	675 lb.
Fuel Weight	195 lb.
Range at Full Speed	255 miles

Performances

The performance below is given from the actual test flights, the ground level of the starting point being 1400 ft. above sea level.

Maximum Speed	86 m.p.h.
Minimum and Landing Speed	38 m.p.h.
Climb to 4000 ft. (pilot, two passengers and full tanks)	10 min.
Climb to 3000 ft. (Pilot alone)	4½ min.
Climb to 8000 ft. (Pilot alone)	17 min.
Climb to 10,000 ft. (Pilot alone)	23 min.
Climb to 15,000 ft. (Pilot alone)	1 hour
Ceiling	17,000 ft.

The New Aerodynamic Laboratory at St. Cyr.



The Above Illustrations Show Some of the Installation of the New Aerodynamic Laboratory at Saint-Cyr, France

Fig 1 shows the aerodynamic balance, which is located in the interior of the great wind tunnel shown in Fig 3.

Fig 2 is an illustration of the chariot which is used for full scale testing of aerofoils and airplanes. The recording instruments are located in the compartments of the box shown open.

Fig 3 affords a general view of the large wind tunnel, with its suction turbine visible at the extreme right. A smaller wind tunnel, not shown here, directs the entering air into the latticework end of the large tunnel and gives it an initial velocity. The object of the latticework is to smooth out the air stream.

Fig. 4 shows a special chariot for propeller testing. The registering instruments are carried in the body of the chariot.

Safety in Flight

Excerpt from a lecture delivered by Air Commodore R. K Bagnall Wild, Royal Air Force, before the Scottish Branch of the Royal Aeronautical Society during March, 1920.

Comparatively brief though the period of post-war civil aviation has been, it has taught many valuable lessons, and has sufficed to demonstrate that, as far as safety is concerned, flying may be placed on an equal footing with any method of transport involving high speed. The statistics published at the close of the first six months of civil flying are confirmation of all that may be said in this respect. Examination of the figures involved reveals the fact that 56,700 passengers were carried in 32,500 flights, covering approximately 480,000 miles, during which a total of 13 accidents occurred causing injury to 10 passengers. Thus the percentage of passengers injured to those carried works out at .017, or in other words, out of every 5,760 carried only one was injured—a result which surely establishes the fact that flying, far from being the perilous adventure it was formerly supposed to be, is a safe and reliable method of transport.

How to Maintain Safety

The question naturally follows—why is it safe to fly, and how can that safety be maintained? In answering the first part of the question it is necessary to consider what factors have chiefly contributed toward accidents in the past. The few civil accidents which have happened up to the present offer too slender a basis numerically to allow of a definite theory being formed on those alone, but a careful analysis of all the accidents, both service and civil, recorded during the past year, shows that a large majority of these were due to error of judgment on the part of the pilot, errors in some cases to be traced to lack of experience, in others to the pilot's indulgence in aerial acrobatics. It is here that that most important factor, the human element, has to be taken into consideration. Although this factor cannot be calculated in terms of mathematics, we have at least the power of selecting our personnel, and I believe that to-day practically all our Transport Companies are in the happy position of being able to command for all their undertakings the services of highly-skilled pilots who were trained in the Service. There is a vast number of such men from which to choose, consequently there is no necessity to incur the risk of any of those accidents which might occur if the machine were in the hands of a novice. The civil pilot, unlike his Service brother, is not undergoing a tuition which aims at making him an aerial acrobat, he is past that stage and is now an expert, with a practical experience which reduces to a minimum the risk of accident contributory to the personal equation.

For these reasons it may be accepted that flying is safe as far as the pilot is concerned, and it should be recognized that these conditions must be maintained. A novice must not be allowed to pilot a passenger machine, he must be trained—and well trained—before being entrusted with such important work.

Several accidents may be traced indirectly to adverse weather conditions, others have been directly due to this uncertain element. But even here we are not opposed by conditions against which nothing can be done, for although we have no control over the vagaries of the weather we have a meteorological organization which is in a position to give timely warning of what may be expected in that direction, especially in regard to air currents, mists and fogs—information vital to the aviator. Forearmed with such information, the scope and value of which steadily increases with scientific research and improved methods of communication, coupled with the use of the excellent instruments with which the modern airplane is equipped, it is reasonable to assume that the number of accidents due to weather conditions will decrease, more especially as this source of accident may to a certain extent be eliminated at the discretion of the user. Regarding instruments, the chief are compass, air speed indicator and altimeter, which assist the pilot to find his way and reduce the risk of accident due to loss of direction and altitude when the ground is invisible owing to weather conditions.

Of the remaining causes, the chief have been engine failures, defects in installation due in some cases to faulty design and in others to insufficient care in daily attention, and failure of structure in which roughly half were due to defective material, but as I propose to touch on this subject at a later stage I will not elaborate these points at the moment.

The study of the question of accidents reveals the fact that the percentage of accidents per hour flown is far greater in Service than in civil flying. The reason for this must be obvious when it is considered that civil conditions only necessitate straight flying at a normal altitude of about 3,000 ft., generally in more or less favorable weather, with a reasonably good taking-off and landing ground provided, and where the aircraft used is a well proved machine, eminently suited for the purpose, inasmuch as it is in no way a stunt machine, but one selected for qualities of stability and reliability proved by past performance. Moreover, the majority of machines in use for passenger carrying at the present time were constructed under war contracts, and whether purchased from salvage or completed subsequently, were manufactured to service specifications—specifications which were undoubtedly rigid, and necessarily so, to meet the severe tests imposed by war flying and therefore of a nature to satisfactorily fulfill the comparatively less exacting requirements of civil use.

In the foregoing remarks I have endeavored to indicate the main factors to which civilian flying owes its present safety, and now pass on to the question of how that safety can be maintained in the future.

As an essential point the aircraft employed must be safe, and such safety is governed by four chief factors, namely, design, materials, construction and operation.

Factors of Safety

Design may be divided into two categories—the aerodynamical requirements and the stress diagram.

Aircraft engineers who are concerned with design may be considered under two headings. On the one hand, the man who deals with the purely experimental side, and on the other hand, the engineer who adapts and correlates knowledge gained by such experiment to meet requirements. It is the user who puts his problems up to the designer, giving his requirements in the way of speed, load, air duration, fuel capacity, etc., and it is up to the works designer, if I may so term him, to solve the problem not only of fulfilling these requirements, but fulfilling them with the maximum efficiency and minimum cost. To attain this end he is not required to solve problems of the air by his own experiment, as he has access to aerodynamical data, but he must be extremely well versed in and possess a wide knowledge of materials, stresses, and composite structures, in relation to their use in the air. To this knowledge, backed by reference when necessary to the existing mass of information available, he adds the product of his own brain, and, by means of stress diagrams, evolves a design. It is at this point that safety is first to be considered, for upon the work put in by him on the drawing board and in his specifications depends safety in flight.

In my opinion, though I am in no way authorized to make any statement on behalf of the Air Ministry, it is at this stage of the proceedings that the Government should be placed in a position to give an opinion as to the suitability of the machine of civil transport. A study of the designer's drawings and specifications would be sufficient to allow of a "type" certificate being promised, subject to the machine being built in conformity with such drawings, and when tested by flight, demonstrating that it has satisfactorily fulfilled the user's conditions. The high standard attained by the industry must be maintained, and to do so there must be no tendency to let commercial capacity influence the designer to the extent of sacrificing safety in his designs for the sake of embodying cheap material.

Regarding materials in general, the necessity for the designer to cut down dead weight to the last ounce has forced the aircraft constructor to search for and employ materials with

outstanding ability to withstand stresses which, in proportion to weight, are much greater than those found in any other type of vehicle or machine. The designer has perforce had to employ factors of safety which allow no precautions to be omitted to ensure that even with the selected materials only the very highest and most uniform qualities are employed. To achieve this end, systematic testing and vigilant inspection have proved to be necessary, not only for metallic materials, such as alloy steels and aluminum alloys, but for other non-metallic materials, such as timber, glue, fabric, dope, etc.

So far as steels and non-ferrous metals are concerned, the existing methods of chemical examination and mechanical testing, although open to improvement, were, nevertheless, standard practice in connection with fine engineering work generally, but in the case of non-metallic material the demands of the aeronautical engineer opened up a new field of work on a variety of materials on which little or no definite information was available. For example, take timber, a material of the highest importance in aircraft construction. Here is a material whose production is not guided by any process controllable by man, and like most organic things, it is apt to suffer from many defects and diseases, some of them so obscure that their detection requires all the resources at our command. Hitherto the general engineer in his use of timber has always employed factors of safety so large that quality and uniformity were matters of secondary importance, but in the case of aircraft we were confronted with the task of devising new tests and drafting new specifications for timber which would ensure the strength/weight ratios which the designer required.

Similarly much work had to be done on fabric, glue, rubber, etc., before we were in a position to specify and ensure the qualities essential for the purpose. The qualities and characteristics of the materials included in that wide range embraced by the requirements of the present-day designer and constructor, are of such importance from all points of view, and especially that of safety, that I propose briefly to detail some of the improvements and developments which have taken place in connection with the manufacture and use of the more important. At the head of these I think we may place the alloys of steel.

Alloy Steels

The term "alloy steel" embraces all that immense range of steels which owe their specially valuable properties to the presence of elements other than carbon. It can fairly be said that much of the progress recorded in the development and construction of aircraft, and particularly the engine, has been brought about by the use of the alloy steels for parts which are subjected to heavy stresses or high temperatures. Crankshafts, connecting rods, camshafts, connecting rod studs and bolts, valves and valve springs, must all do duty under conditions which render the use of the plain carbon steels inadmissible on account of either weight or temperature considerations.

Alloy steels can now be specified with considerable precision, and under the various specifications for aircraft steels which are issued by the British Engineering Standards Association, comparatively close limits of analysis are laid down. The user of the steel is therefore assured of obtaining the proper quality if ordered to the appropriate specifications. For example, an alloy steel is required which will give a tensile strength of from 55 to 65 tons per square inch. The specification prescribes the following composition.—Carbon, 0.28 to 0.34 per cent. Manganese, 0.45 to 0.70 per cent. Nickel, 3.00 to 3.75 per cent. Chromium, 0.5 to 1.00 per cent. Sulphur and phosphorus, not more than 0.05 per cent each.

The consideration of machining and wearing properties constitutes an important factor in the choice of a steel, particularly as regards analysis. Experience has shown that an alloy steel is a material which needs scientific handling from the time of its making until the completion of the finished article. In all cases an exact knowledge of the particular heat-treatment necessary is of supreme importance if the highest qualities of the steels are to be secured, and a full knowledge of the chemical composition is essential to ensure that correct heat-treatment is applied. Adequate indication of wrong heat-treatment is secured by the usual tests (tensile, shock and hardness), and the microscope is a most valuable supplementary weapon to the inspector.

Probably no steels are required to withstand more extraordinary conditions of service than valve steels. The steel must be able to resist exposure to high temperature without excessive scaling, without distorting, without deteriorating appreciably in strength, and without surface abrasion in the stem, which would cause undue friction in the guides. The exhaust valve conditions are the more severe, to meet which the aeronautical engineer has made use of "high-speed" tool steels and "stainless" steel.

The former steel is used for exhaust valves in the hottest running engines; it is a tungsten steel having a carbon content of 0.55 to 0.70 per cent with tungsten over 14 per cent and chromium over 3.5 per cent. Valves made from this steel will work successfully even above 800 deg. C., i. e., a bright red heat. For moderately hot engines of the water-cooled type, the "stainless" steel, having a carbon content of between 0.40 and 0.70 per cent and a chromium content between 8 and 12 per cent., is successfully employed. Valves in this steel will withstand a running temperature up to 750 deg. C., i. e., a full red heat. For inlet valves a 3 per cent nickel steel has proved eminently satisfactory.

Aluminum Alloys

As regards light alloys, the continuous development of the alloys of aluminum has had a marked effect on the progress of the airplane and aero-engine. Much time and thought have been given and much patient labor expended in the foundries in the effort to overcome the many difficulties connected with casting of these light alloys.

It is comparatively easy for the designer to produce a drawing of a crank case, a cylinder, or a piston, which will be much lighter than the corresponding article made in iron or steel, and which will be strong enough and stiff enough for the duty it has to perform in the engine, but it is by no means easy to ensure that the article can be successfully cast. The designer has to co-operate with the founder especially with regard to thickness of the walls of the casting to enable the use of the comparatively low temperatures which are necessary to soundness, and the design must be such that the metal flows into the mold always pushing the air before it, and thus avoiding air locks. In the foundry itself we have learned that with these light alloys it is essential to maintain scrupulous cleanliness in the sand, the boxes, the melting pots, and in the metal itself. Great attention must be paid to the melting—the rate of heating must not be too rapid, the temperature must be checked by pyrometer, a temperature of 700 deg. C. in the pots must not as a rule be exceeded, and care must be exercised to obtain a uniform temperature throughout the mass of molten metal before it is poured.

In the molds, cores must be fragile enough to crush as the metal contracts and so avoid strains in the castings. Often it is necessary to use metal chills to regulate the rate of cooling of the various parts of the casting and so relieve internal stress.

As to the metal employed, it is not advisable to employ scrap if uniformly strong castings are required, and in aircraft work virgin metal must be insisted upon for all important castings.

The light alloys have been specially applied to pistons, crank cases, and cylinders of aircraft engines. The advantage of using a piston or cylinder of aluminum alloy arises out of the higher heat conductivity, which is three times that of cast iron. In the case of the piston the compression ratio of the engine can in consequence be increased, at once raising the efficiency of the engine. Although a higher compression ratio means a higher explosion temperature, the heat in excess of that which will allow of reciprocity without seizing, is conducted away more rapidly through the thicker walls of the piston, and the piston actually runs cooler than does a cast iron piston. There is little difference in the weight of the two pistons. The use of aluminum alloys for cylinders has not yet become general practice. There is practically no saving of weight in the use of a cylinder of aluminum instead of steel since the walls must be thicker and a steel liner provided.

All-Metal Construction

There seems little doubt that the future development of aircraft design will involve the inclusion of an all-metal construction. Several examples of all-metal airplanes, more especially of the fighting machine type, were used during the

war, though not by us. Metal has several advantages over wood. First of all, there is the greater certainty of quality. The process of steel manufacture can be controlled all the way through, and defects, at any rate in the case of thin sections, cannot remain unnoticed. Timber, on the other hand, is a natural product; it must be used in large sections and defects are difficult to discover; furthermore, it is affected by atmospheric conditions.

The present-day all-metal machines are primarily built up of thin, cold rolled sheet steel of thicknesses from 0.015 in. to 0.022 in. This steel may be plain carbon or alloyed with nickel and chromium. The carbon steel requires to be tempered at about 400 deg. C. after cold rolling, and then possesses a tensile strength of from 65—70 tons per sq. in. The alloy steel strip can be obtained in a condition suitable for punching, bending and welding, with an ultimate strength of over 100 tons per sq. in. It is manufactured by the process of cold-rolling, annealing between each pass, and finally hardening and tempering. A careful control of heat-treatment and avoidance of undue cold work is essential to ensure safety.

Duralumin is also available for metal airplane construction, and this material promises to resist corrosion better than steel; it must, however, be very carefully heat treated or its strength will be greatly impaired. It has only a maximum strength of about 26 tons per sq. in., but on the other hand, it has only one-third the specific weight of steel.

After manufacture, the sheet metal, whether steel or duralumin, is built up into spars and struts, stiffness being obtained by longitudinal corrugations. A great advantage of metal construction in spars or struts is that practically all the metal in the section can be so disposed as to take its full share of the load. In a wooden spar this is not possible. As to weight, metal spars in steel can now be made as light as 0.5 lb. per foot run as against 0.65 lb. to 0.85 lb. per foot run for wooden spars of equal strength. In the case of struts for the largest machines of to-day, wooden struts are often 50 per cent heavier than metal struts of greater stiffness and strength.

The chief difficulty with metal constructional work is corrosion and it can scarcely be said as yet that the problem is solved. Such being the case, timber still holds its position of importance in the aircraft world.

Wood Construction

In the choice of timber for use in aircraft, one would at first imagine that out of the plethora of timber in the forests of the world, unlimited supplies of any given quality of material would be available.

This, however, is not the case. To meet the insistent demands of designers it is probably no exaggeration to say that literally hundreds of types of timber have been critically examined and ultimately discarded as unsuitable for aircraft manufacture. The result of this long process of elimination is that only those woods having exceptional qualities of stiffness, strength, and uniformity of growth are now used for this important purpose.

Out of the mass of timber available, it soon became clear that for anything like economical bulk production only the pine-like cone-bearing trees could be considered. Of these coniferous woods the Alaskan or Sitka (or silver) spruce of North America was found to be the best, and upwards of 90 per cent of the timber used during the war in the construction of aircraft was of this variety. The trees that supply this timber grow over a limited area only of the Pacific Coast Watershed of the British Columbia region.

In the same way that silver spruce proved itself to be the timber par excellence for the main members of the wing structure, English ash has shown itself to be without parallel for use in fuselage-longerons, engine bearers, wing-tips, etc., while walnut and mahogany are equally unrivalled for use in propeller work.

In dealing with these hard wood timbers, great difficulties were encountered during the war. While from the outset spruce could be obtained in a reasonably dry condition, supplies of dry English ash were non-existent; and dry mahogany and walnut could only be obtained in wholly inadequate quantities.

This situation led to the erection of seasoning kilns in all parts of the country for artificially drying these timbers, and on a scale far beyond anything ever attempted before. Thus, during the war, over 8½ million superficial feet of this type of material were dried under the supervision of Government inspectors in special drying kilns erected for coping with this branch of work. (The exact amounts were:—English ash, 2,100,000 ft.; mahogany, 2,700,000 ft.; walnut, 3,700,000 ft.)

So successful was this work that it is not too much to say that the kiln-dried timber was fully equal, if not superior, to the best naturally seasoned timber. Many business firms in this country are now continuing the use of these kilns and employing the methods introduced by war conditions. Incidentally, a gratifying feature of the work was the appreciation expressed during the war by the representatives of the Allied Governments, especially those from America, at the high standard of efficiency of British kiln drying.

During the last few months of the war the A. I. D.* developed a method of examining aircraft timber and timber workmanship by means of the X-rays. This method, which is only in its infancy, gives promise of being a valuable supplementary aid to existing methods of timber inspection.

Book Review

AEROPLANE DESIGN. S. T. G. Andrews and S. F. Benson (454 pp.) E. P. Dutton & Co.

In this book, which undertakes to cover the whole field of airplane design, there are parts which are good and others not so good, reflecting perhaps the experience of the authors in each department of the subject. As a whole the writers have succeeded very well in producing a book which is well balanced, as judged by an engineer. The chapter on stability is appropriately compressed and explained for the above (the engineer's) brand of mathematics.

Much of the aerodynamical data is old, and while of value for the purpose of illustrating general principles, is hardly to be considered useful for the direct application of numerical values. In particular the aerofoils on which complete data are given are unidentified although the statement is made that they "have proved themselves efficient in flight." The data on scale and biplane corrections are very meager. Of a later chapter on resistance of various parts the same criticisms may be made concerning much of the data.

The chapters devoted to structural design are good. The methods are sound and as refined as would be expected in a book of this scope. Rather more attention is given to tapered struts than will be found necessary in practice. The structural tables and diagrams are well made. Loads experienced by the principal parts of the airplane are discussed for the more usual conditions of flight. This discussion is quite clear but cannot be said to follow the latest practice in regard to load factors.

A short treatment of propeller design is included and uses a blade element or aerofoil theory without consideration of inflow. Stresses in the blades are found in the more usual elementary fashion.

The chapter on the design of control surfaces is a good theoretical discussion based on wind tunnel tests. The empirical but more workable method of coefficients based on successful machines is not touched upon.

Methods of performance calculation and testing are treated in a clear concise manner. The general layout of the airplane is also well and tables of data on representative British machines form a valuable basis for the design.

Trade Review

DIE CASTINGS.—Doehler Die-Casting Co., Brooklyn, N. Y.

The Doehler Die-Casting Company issues two beautiful booklets describing their brass and white metal castings respectively. The brass and bronze "Do Di" Castings are finished to tolerances of about 0.2 per cent, eliminating most machine work and defective castings. The physical properties may be varied through a wide range. Tensile strengths up to 70,000 lbs., elongations up to forty per cent and hardness from 40 to 100 Brinell, are available.

The second booklet, "Creating an Industry," follows the history of the art of making castings from ancient times to the present. The chemical and physical properties of a number of aluminum, zinc, tin, and lead alloys, are given.

* Aeronautical Inspection Department, British Air Ministry.—EDITOR.

A New High Performance Wing

A novel form of airplane wing, which appears to go a long way toward improving the economy of commercial flight, has just been introduced in England under the name of Alula wing. The aerodynamic data and the outline of the new wing are given below. Although in its present form the wing marks a great improvement on the ordinary aerofoil for load carrying at moderate speeds, it does not, in the opinion of the inventors, represent the maximum attainable.

The chief characteristics of the Alula wing are a straight trailing edge, a negative dihedral leading edge, a deep camber, and a wash-out in chord, camber and incidence toward the tip. In addition to scale model wind tunnel tests, full scale experiments have been made for some time by the technical staff of the Blackburn Aeroplane and Motor Co., of Leeds, in order to determine the agreement between model and full scale work. These trials are still in progress, but it is stated that very satisfactory results are being obtained.

Angle of Incidence Degrees.	$K_y \cdot 10^3$	L/D	Center of Pressure Co-efficient
0	9.7	7.0	0.575
1	12.3	10.5	0.488
2	14.8	12.3	0.447
3	17.2	15.8	0.432
4	19.7	18.5	0.414
5	22.1	20.6	0.408
6	24.5	22.2	0.395
7	26.8	22.85	0.388
8	28.8	22.8	0.388
9	31.7	22.5	0.381
10	33.7	21.8	0.378
11	36.2	20.9	0.371
12	38.6	19.85	0.365
13	40.8	18.8	0.350
14	42.0	17.5	0.340
15	42.2	16.1	0.335
16	42.0	14.6	0.335
17	41.5	12.9	0.340
18	40.9	10.8	0.352
19	40.8	8.8	0.369

A reference to the accompanying table will show that not only is the maximum lift coefficient unusually high, but the maximum L/D and the lift coefficient corresponding to maximum L/D are also extremely good. The maximum lift coefficient is 42.2 and occurs at an angle of incidence of 15 deg. As the maximum lift coefficient of the ordinary wing is somewhere between 25 and 30 it will be seen that, for the same landing speed, the wing area can be reduced to about three-fourths that necessary with the ordinary wing. This is not the only, nor perhaps the greatest, advantage of the Alula wing, as it is called by the designers. The maximum L/D (to which scale correction still has to be added) is as high as 22.9, which compares favorably with the orthodox wing, and the lift coefficient corresponding to this maximum L/D is 28.8, or as high as the maximum lift coefficient of the average wing. This, it will be seen makes for economy of flight, especially in machines carrying a high load at moderate speeds.

The "Pelican" 4-Ton Lorry

An interesting example of a cargo-carrying design using Alula wings is the cantilever monoplane. The wings and fuselage are both constructed of mahogany planking on the principle used in modern flying-boat hulls; this simplifies the machine and eliminates the bulk of the metal parts, fabric, etc., and will give great durability, a feature of the first importance in relation to depreciation charges.

The machine is a non-folder, being designed to dispense with shed costs altogether.

The crew consists of a pilot carried right forward and a mechanic in charge of the engine-room aft. The engines are twin Napier Lions, and the machine is designed to fly and climb even if one engine breaks down. Reliability of service is assured by this power to fly on one engine and by the superintendence of the engines in flight, coupled with the fact that all work is normally done at half-power.

The design has been prepared on a most conservative basis in all respects; for instance, an allowance of 7½ per cent on all structure weight above the calculated figure has been included, and the factor of safety has been taken as 5 in the calculations, whereas 3 is nearer the ultimate mark for cargo machines; further, a 30-m.p.h. head wind is assumed in calculating the weight of fuel carried.

Specifications	
Span	148 ft.
Length	84 ft.
Height	22 ft.
Chord	16 ft.
Fuselage diameter	14 ft.
Weight—	
Wings	3,100 lb
Fuselage	3,080 lb
Tail	880 lb
Chassis	1,130 lb
Structure	8,190 lb
7½ per cent. addition	690 lb
Tanks	550 lb
Engine and propeller mountings, radiators, silencers, etc	870 lb
Engines	1,880 lb
Crew	360 lb
Empty	13 440 lb
Fuel (400 miles)	2 770 lb
Cargo (400 miles)	7,950 lb
Total	24,160 lb
Performance—	
Landing speed	55 m.p.h.
Cruising speed	72 m.p.h.
Climb	410 ft per min
Climb on one engine	40 ft per min
Cruising revolutions	0.80 of normal
Cruising B H P	0.51 of normal

Trade Reviews

Compendium of Aircraft Equipment. (96 pp. with many illustrations, prepared by Brown Brothers, Ltd., London, Eng.)

While this catalogue of aircraft and aerodrome equipment constitutes a trade publication, it is surprisingly well got up and is extremely valuable. It includes excellent photographs of a number of well known British machines, photographs of the best known engines, and is in many respects a better book on the commercial aspects of aeronautics than orthodox books on the subject.

It gives exact dimensions in well arranged tables, specifications and prices for such parts as nuts, eye bolts, studs, thimbles, locking wires, standard wire ferrules, washers, pins, gasoline filters, plugs, gasoline connections of various types, gasoline tank connections, relief valves, drain cocks, standard screws of all kinds, rivets, control pulleys, turnbuckles, streamline wires, swaged wires, steel tubing of various kinds and other metal parts.

Aircraft instruments of every kind are included. The Brolt Dynamo Lighting Equipment as used on the R 34 is also described. Sundries of every description are listed from upholstery materials to spark plugs. Aerodrome accessories are listed such as the Imperial Night Landing Lights, gasoline tunnels, starting sets and so forth.

The catalogue should be of real value to anyone engaged in the industry whether in construction or transportation.

Jeffery's Marine Glue. L. W. Ferdinand & Co., Boston, Mass.

This booklet describes a wide line of waterproof glues, many of which are useful in aircraft construction, particularly for hulls and pontoons. Directions for use in obtaining the best results are given in some detail. Quantities required for various purposes are listed, as well as prices.

Effects of Nature of Cooling Surface on Radiator Performance. Synopsis of Report No. 87 National Advisory Committee for Aeronautics.

This report discusses the effects of roughness, smoothness, and cleanness of cooling surfaces on the performance of aeronautic radiators, as shown by experimental work, with different conditions of surface on (1) heat transfer from a single brass tube and from a radiator, (2) pressure drop in an air stream in a single brass tube and in a radiator, (3) head resistance of a radiator, and (4) flow of air through a radiator. It is shown that while smooth surfaces are better than rough, the surfaces usually found in commercial radiators do not differ enough to show marked effect on performance, *provided the surfaces are kept clean.*

Properties of Special Types of Radiators *

By S. R. Parsons

Bureau of Standards

In respect to the relation of power absorbed to power dissipated, flat plate radiators have been found to be markedly superior to other types commonly employed, for use in unobstructed positions on airplanes flying at the higher speeds.

For such use, a pitch of ½ in. (1.27 cm.) between plates gives a higher figure of merit than the closer spacings.

The depth of such a radiator should be considerably greater than of the honeycomb types, and the most efficient depth is greater with the higher speeds. For a radiator of ½ in. pitch to be used at a speed of 120 m.p.h. (53.6 m.p.s.), the most efficient depth appears to be about 13 in. (33 cm.). A small increase above this depth has but a slight effect, however, on the figure of merit, and if it is desirable to reduce the frontal area of the radiator to a minimum, the depth may be increased to 20 in. (51 cm.) or more without serious reduction of efficiency.

Equations and plots are given, by means of which the properties of flat plate radiators may be obtained for various depths and spacings.

The plates should be continuous from front to rear of the radiator, in order to avoid excessive head resistance caused by eddies in the air stream.

For the study of heat dissipation, three radiators were used, each 9¾ in. deep and with plates 1-16 in. thick, spaced ¼, ⅜, and ½ in. respectively, center to center.

For the study of mass flow of air through the core and of head resistance, a set of 22 dummy radiators were constructed, using depths of 2, 4, 8, and 12 in., spacings of ¼, ⅜, ½, ¾, and 1 in., and thicknesses of 1-16 and ⅛ in. The plates were

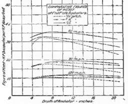


Fig 1

made by covering cardboard of the proper thickness with thin sheet copper, and were used again and again. They were 12 in. long and with the exception of the ¼ in. spacing, enough were used to make a radiator 12 in. wide, so that the frontal area was 1 sq. ft. Since the copper was thin it was not possible to obtain as smooth a surface as might have been desired, but the condition was fairly representative of what would be found in commercially manufactured radiators.

Extrapolations for depths of radiators not covered by the laboratory tests were made with the use of three empirical equations, given below. All quantities are based on one square foot frontal area of the radiator and an air density of 0.0750 lb./cu. ft.

* Report No. 86, National Advisory Committee for Aeronautics

Mass flow of air is given by the equation

$$M = 0.110 \sqrt{\frac{p-t}{p}}\,(V)\left(1 - e^{-20.05\sqrt{\frac{p-t}{x}}}\right) \quad (1)$$

where M = mass flow of air in pounds per second per square foot frontal area of radiator,
V = free air speed, in miles per hour,
t = thickness of plates, in inches,
p = pitch, in inches,
x = depth of radiator, in inches; and
e = base of natural logarithms.

Heat dissipation is given by the equation

$$Q = 34.6\, M\left(1 - e^{-\frac{Bx}{MA}}\right) \quad (2)$$

where Q = heat dissipation in h.p. per 100 deg. F temperature and A and B are empirical constants.

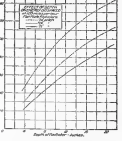


Fig. 2

The constants A and B were determined from actual heat tests on the three radiators mentioned above, and are as follows:

¼-in. pitch: $A = 0.24$; $B = 00.0616$;
⅜-in. pitch: $A = 0.11$; $B = 0.0283$;
½-in. pitch: $A = 0.23$; $B = 0.0258$.

It was assumed that the head resistance might be regarded as made up of two parts, (1) that due to the impact of air on the edges of the plates, including suction on the rear, and (2) that due to skin friction of the air passing over the plates. The results were very well represented by the equation

$$R = n\, V^2\,(0.00016\, t + 0.0000025\, x) \quad (3)$$

where R = head resistance in pounds per square foot frontal area; and n = number of plates per foot width of core.

The values given by this equation are a little low when n equals 48; i.e., with ¼-in. pitch, but for spacings greater than ¼ in., the resistance per plate was found to be constant for a given speed and air density.

The weights of the radiators and the water contained in them were estimated from geometrical considerations and the densities of copper and solder, assuming the Lepere type of construction. The weight is given by the equation

$$W = 0\,0557\ n\ x \qquad (4)$$

where W = weight of core and contained water, in pounds per square foot frontal area.

A lift-drift ratio of 5 4 was assumed for the airplane, and the horsepower absorbed (per square foot) is

$$H\ P. = \left(R + \frac{W}{5\,4}\right)\left(\frac{V}{375}\right) \qquad (5)$$

Figure of merit is the ratio of the power dissipated to the power absorbed

$$F\ M = \frac{Q}{H\ P.} \qquad (6)$$

The following example illustrates the use of the equations Let it be required to obtain the figure of merit of a radiator with plates 1-16 in. thick, ½ in pitch, 16 in. deep, and at 120 m p.h.

In equation (1) for mass flow of air,

$$M = 0\,110 \sqrt{\frac{p-t}{p}}\ (V)\left(1 - e^{-10\,85 \sqrt{\frac{p-t}{x}}}\right)$$

p = pitch = 0.5
t = thickness = 1-16 = 0.0625
x = depth = 15
V = speed = 120

$$M = 0.110 \sqrt{\frac{0.5-0\,0625}{0.5}}\ (120)\left(1 - e^{-10\,85 \sqrt{\frac{0\,05-0\,0625}{16}}}\right)$$

$M = 0.110\sqrt{0\,875}\ (120)\ (1 - e^{-1\,81})$
$M = 12.35\ (0\,836) = 10\,33$ lb. per sq. ft. per sec.

In equation (2) for energy dissipated,

$$Q = 34.6\ M\left(1 - e^{-\frac{Bx}{MA}}\right)$$

$A = 0\,23$
$B = 0\,0258$

$$A = 34.8.(10\,33)\left[1 - e^{-\frac{(0\,0258)\ (16)}{10\,33\ ^{23}}}\right]$$

$Q = 359\ (1 - e^{-0\,241}) = 359\ (0.215)$
$Q = 77.3$ H. P. per sq. ft. per 100° F.

In equation (3) for head resistance,
$R = n\ V^2\ (0\,0016\ t + 0\,0000025\ x)$,
$n = 24$

$$R = 24\ (120)^2\left(\frac{0\,00015}{16} + 0\,0000025\ (15)\right)$$

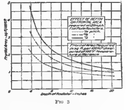


FIG 3

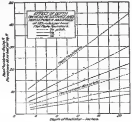


FIG. 4

$R = 24\ (120)^2\ (0\,00001 + 0.00004)$
$R = 17\,27$ lb per sq ft
From equation (4),
$W = 0.0557\ (16)\ (24) = 21\,4$ lb. per sq ft.
From equation (5),

$$H\ P. = \left(R + \frac{W}{5.4}\right)\left(\frac{V}{375}\right)$$

$$H.\ P. = \left(17\,27 + \frac{21\,4}{5\,4}\right)\left(\frac{120}{375}\right) = 6.80\ H\ P. \text{ per sq ft.}$$

From equation (6),

$$F.\ M. = \frac{Q}{H\ P} = \frac{77.3}{5\,80} = 11\,4$$

Description of Curves

Plot 1 shows figure of merit computed with the aid of the above equations for various depths and for speeds of 60, 90,

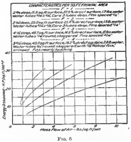


FIG. 5

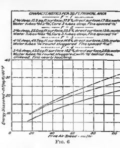


FIG. 6

and 120 m.p h , and for spacings of ¼, ⅜, and ½ in. between plates. The curves illustrate the following points

(1) The ½ in. pitch gives, in general, a higher figure of merit than those of closer spacings.

(2) For high speeds the radiator may be somewhat deeper than for low speeds.

(3) For the higher speeds the most efficient depth is considerably greater than those in common use with the cellular types of core.

(4) For the higher speeds, the figure of merit is practically at its maximum value over a considerable range of depth, so that if considerations of compactness make it desirable to reduce the frontal area to a minimum, a reasonable increase in depth beyond the optimum will have but a small effect on the figure of merit

The effect of depth on the properties of the radiator is shown

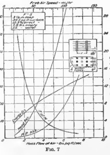


FIG. 7

in plots 5, 6, and 7. The values of "area required per 100 hp." in plot 6 are 100 times the reciprocals of the corresponding values of energies dissipated (in hp /sq. ft.) of plot 2.

The following example illustrates one way in which the curves may be used. For a radiator with ½ in. pitch, to be used at 120 m.p.h , the maximum figure of merit is given on plot 1 as 11 7 at 13 in depth. From plot 6, the frontal area of radiator required with 13 in depth is 1.55 sq ft. per 100 hp. If, in order to reduce the frontal area, a depth of 20 in. should be used, the area required would be 1.10 sq ft. per 100 hp. (from plot 6), and the figure of merit would be 11.0 (from plot 1). The horsepower absorbed would be increased from 5.5 to 5 1 per sq ft. (plot 7) Since, however, the frontal area may be reduced in the ratio $\frac{1.10}{1.55}$, the actual power absorbed that should be compared with the value for 13 in. depth would be $\frac{1.10}{1.55}$ (8.1), or 5.75. These results may be summarized as follows.

	13 in	20 in	Change. Per cent.
Area required, sq ft./100 hp	1.55	1 10	—29
Horsepower absorbed, per square foot required at 13-inches	5 8	5 75	+ 3
Figure of merit	11 7	11 00	— 6

A careful distinction should be made between radiators whose water tubes are smooth, flat plates and other types using perforated plates, or deep and narrow tubes placed in rows,

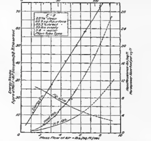


FIG. 6

one behind the other. Holes in the water tubes, or spaces between them in the direction of the air flow, cause very great increase in head resistance and decrease in mass flow of air; and although the heat transfer per square foot of cooling surface may be increased by the great turbulence caused, it is at a very heavy cost in head resistance, and with a decrease in figure of merit.

The effect of holes in the water tubes, and of spaces between them in the direction of the air flow is taken up later in this report under "Properties of whistling radiators," in which the properties of six such types are given.

Properties of Fin and Tube Radiators

Radiators of the "fin and tube" types are characterized by high head resistance, and low heat transfer at high speeds. With the possible exception of certain compact types for use in the wing they are unsuitable for airplane use.

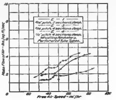


Fig. 9

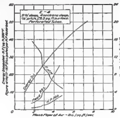


Fig. 12

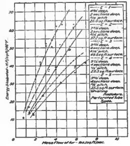


Fig. 10

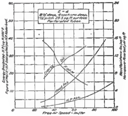


Fig. 13

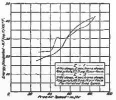


Fig. 11

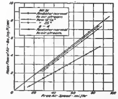


Fig. 14

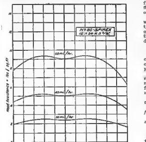


Fig. 15

The properties of "fin and tube" types of cooling radiators are distinctly different from those of the better cellular types and warrant special mention.

In general, the fin and tube types are characterized by high head resistance and by low heat transfer at high speeds. The low heat transfer is accounted for by the small flow of air through the radiator and by the large amount of indirect cooling surface. For radiators as ordinarily made with depths of 5 in. or less, head resistance has been shown to be due principally to the impact of the air on the front face and suction on the rear, and only to a small degree to skin friction on the walls of the air passages. With the fin and tube construction the effects of impact and suction are exaggerated; for each separate water tube is subjected to impact on one side and suction on the other, with the result that the total (projected) area subjected to impact and suction—on all tubes—is much greater than that necessitated in a radiator of the same size but of cellular construction. To the effect of this impact and suction must be added the effect of skin friction on the fins.

Excessive head resistance, accompanied by low heat transfer, make the fin and tube types unsuitable for use on an airplane where they would be exposed to a current of air at a high speed. The more compact types, however—notably F-4, which has large water tubes with crimped spiral fins nearly touching each other—show a relatively high rate of heat transfer at very low speeds, which justifies their extensive use on trucks and lower speed automobiles. Indeed the type F-4 would doubtless dissipate a considerable amount of heat with convection currents only.

The accompanying curves show the heat transfer (energy dissipated) for five types of core, in terms of the mass of air flowing through the core. The heat transfer is expressed in horsepower per square foot of frontal area, for a difference of 100 deg. Fahr. between the mean temperature of the water and the temperature of the entering air. Mass flow of air is expressed in pounds per second per square foot of frontal area. Energy dissipated is also shown in terms of free air speed; that is, the speed of the machine on which the radiator is mounted. Plot 3 shows also the figure of merit of the radiator, which is the ratio of the horsepower dissipated to the horsepower absorbed.

The attempt to undermine the relation between the mass flow of air through the core and free air speed was unsuccessful in the case of the type F-4 (with spiral fins); for the air flow was too small to be measured with the instrument used on the other radiators.

In general, it may be stated that fin and tube radiators are unsuitable for airplane use, with the possible exception of a type similar to F-4, placed in the wing, where the mass flow of air must be very small (even less than for the nose portion), and consequently head resistance is not necessarily a detriment.

Properties of Whistling Radiators

The construction of some types of radiators is such that at certain air speeds they produce a whistling sound. These so-called "whistling radiators" are characterized by the following points

(1) Unusual conditions of air flow, resulting in irregularities in the relations between different properties. For example, mass flow of air through the radiator is not proportional to free air speed as in ordinary radiators, and head resistance is not proportional to the square of free air speed.

(2) High heat transfer *for a given mass flow of air through the radiator.*

(3) Very low flow of air through the radiator *for a given free air speed.*

(4) In many cases, low heat transfer *for a given free air speed.*

(5) Very high head resistance and horsepower absorbed.

(6) Low figure of merit.

If water tubes made of smooth flat plates, continuous from front to rear of the radiator, are substituted for the rows of tubes of the whistling radiators described, the figure of merit will be greatly increased

Certain types of cooling radiators that whistle in an air stream show peculiar properties, and while radiators of this construction are not recommended, they are being used to some extent, and appear to be worthy of special mention.

Types of Core Tested

The whistling radiators tested at the Bureau of Standards fall into two general classes:

(1) Plain water tubes, and

(2) Perforated water tubes.

The photographs show the forms of construction. In each case the radiator is made up of separate water tubes about 2 in. deep (in the direction of air flow), arranged in rows. In addition, the plain tube type has fins spaced 2 in. apart.

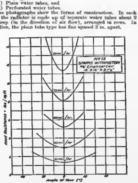


Fig. 16

The test sections included one of the plain tube type, designated as E-9, and five perforated tube types, made up in different depths, and with different spacings between rows of tubes. These sections are designated as follows:

E-1, 5-16-in. pitch, 2 tubes deep
E-2, 5-16-in. pitch, 3 tubes deep.
E-3, 5-16-in. pitch, 4 tubes deep.
E-4, ½-in. pitch, 4 tubes deep
E-5, ⅝-in. pitch, 4 tubes deep.

Cause and Effect of the Whistle

The form of construction leaves continuous air passages *across* the radiator, that is, perpendicular to the direction of the air stream. In the plain tube type these air passages occur between the water tubes, and in the perforated tube types not only between the tubes but at each perforation. All through the radiator there are short columns of air, across the ends of which air is blowing, with the result that vibrations are set up in the short columns and perpendicular to the air stream. The resulting whistle will of course vary widely in intensity and in pitch as the speed of the air stream varies, and conditions of resonance have very marked effects, not only upon the sounds, but upon the properties of the radiator.

By the vibrations of the cross columns, air is alternately being forced into and withdrawn from the fast moving stream. Air drawn out of the stream will be retarded and air forced into it will be accelerated, thus acting as a drag on the stream. These two effects cause a great decrease in the flow of air through the radiator and a great increase in head resistance.

At the same time the very great turbulence caused in the air stream results in a high heat transfer per square foot of cooling surface *for a given mass flow of air through the radiator*, and this increase in heat transfer may be so great as to counterbalance the decrease in air flow, but is not great enough in any case observed to overcome the disadvantage of the increased head resistance.

Description of Curves.

The accompanying curves show the properties of the six types of radiator, expressed as follows (all values have been reduced to an air density of 0.0750 lb./cu. ft.):

Free air speed, in miles per hour.

Mass flow of air through the radiator, in pounds per second per square foot frontal area.

Energy dissipated, in horsepower per square foot per 100 deg. Fahr., difference between the temperature of the entering air and the mean of the temperature of the entering and leaving water.

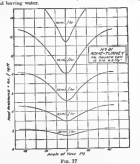


Fig. 17

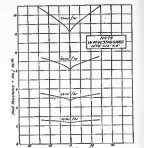


Fig. 18

Head resistance, in pounds per square foot frontal area.

Horsepower absorbed, in horsepower per square foot frontal area.

Figure of merit is the ratio of the horsepower dissipated to the horsepower absorbed.

Plot 1 shows the properties of the plain tube type, E-9. Its heat transfer is high, but its head resistance is also high, and the figure of merit is low. The great weight of the radiator accounts for its very low figure of merit at low speeds.

The relation between the mass flow of air through the radiators and free air speed is shown for three of the perforated tube types in plot 2. For ordinary radiators this relation is linear and it is practically so for the plain tube whistling type. The irregular form of these curves shows clearly the effect of the peculiar conditions of air flow in the radiator, the sudden changes in slope of the curve corresponding to sudden changes in tone of the whistle.

Plot 3 shows energy dissipated (heat transfer) in terms of mass flow of air. The curve for the type E-4 was determined by interpolation,* since the water boxes had been removed in order to measure its head resistance. Too much importance should not be assigned to the fact that some of these curves show a high heat transfer with a given mass flow of air, for Plot 4 shows that the highest curve of Plot 3—that for E-3, four tubes deep, 5-16 in. pitch—becomes low when heat transfer is plotted against free air speed.

Plots 5 and 6 show the complete properties of the type E-4, in terms of mass flow of air, and in terms of free air speed, respectively. The curves are reliable within the ranges covered, but the irregular relation between mass flow of air and free air speed makes extrapolations extremely doubtful.

Head resistance of ordinary radiators is nearly proportional to the square of free air speed, but the irregularities in the head resistance curves of Plots 1 and 6 show that this is not the case with the whistling types.

Comparison Between Whistling Radiators and Flat Plate Radiators.

The foregoing statements should not be interpreted as applying in any degree to radiators whose water tubes are flat plates with smooth surfaces, and continuous from front to rear of the radiator.

* Types E-3, E-4, and E-5 are each four tubes deep, and are five-sixteenths, one-half, and five-eighths inch pitch, respectively. The heat transfer for E-3 and E-5 was found to be proportional to the number of tubes per foot width of front, and this proportionality was used in interpolating for E-4.

The whistling types are characterized by low air flow and often low heat transfer (for a given free air speed), by high head resistance, and by a low figure of merit, but the flat plate types are characterized by high air flow and heat transfer (for a given free air speed), by low head resistance, and by a high figure of merit. The following comparative tables show the superiority of the flat plate types over the whistling types.

TABLE I.

Perforated Tube Type and Flat Plate Type of the Same Pitch and Practically the Same Depth.

Type	E-4 perforated tube	E-8 flat plate
Pitch, inches	0.5	0.5
Depth, inches	2.50	2.75
Cooling surface, square feet, per square foot front	29.5	39.2
Mass flow of air, pounds per second per square foot	6.76	5.48
Type	**E-4, perforated tube**	**E-8, flat plate**
Energy dissipated, horsepower per square foot per 100 deg. Fahr.	30.8	28.8
Head resistance, pounds per square foot	6.72	3.12
Horsepower absorbed per square foot	1.75	.92
Figure of merit	17.8	32.4

Test data are not available for a direct comparison of plain tube and flat plate types of radiator of the same pitch, but the plain tube whistling type E-9 of three-fourths inch pitch may be compared with flat plate types of one-half inch pitch. It was previously shown that for flat plate types a pitch of one-half inch is better at high speeds than the closer spacings, and there seems to be no reason to suppose that a pitch of three-fourths inch would be less efficient. A comparison of the two types would appear to give an advantage to the one of three-fourths inch pitch. Two depths of the flat plate type are

Fig. 19

considered, giving approximately the same direct cooling surface (not including fins), and the same actual depth of tubes, respectively, as the whistling types. A plain tube whistling type H-3, described in a French report, is also included

TABLE II

Comparison of Flat Plate and Plain Tube Radiators

Free air speed, 120 miles per hour

Type	Flat plate	Flat plate	E-9 plain tube
Pitch, inches	0.5	0.5	0.75
Depth, inches	1.0	2.0	2.25
Direct cooling surface	61.0	60.5	61.7
Mass flow of air	10.58	9.61	8.96
Energy dissipated	77.4	90.5	81.8
Head resistance	17.1	20.8	25.9
Horsepower absorbed	6.7	8.2	11.2
Figure of merit	11.5	11.0	7.3

Free air speed, 90 miles per hour.

Type	Flat plate	H-3 plain tube.	Flat plate	E-9, plain tube
Pitch, inches	0.5	0.57	0.5	0.75
Depth, inches	1.0	1.58	2.0	2.25
Figure of merit	18.0	18.5	18.0	10.8

Conclusions.

The above tables seem to show clearly that any increase in heat transfer caused by perforations in the water tubes or spaces between them in the direction of air flow is at the expense of a great increase in head resistance and is accompanied by a decrease in the figure of merit. The same result has been found in the case of turbulence vanes in cellular radiators, and indeed no type of radiator is known to this bureau in which an artificial increase of turbulence is not accompanied by a decrease in figure of merit. For use in obstructed positions, such as the nose of the fuselage, it may

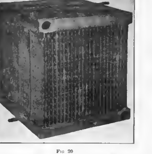


Fig. 20

be necessary to sacrifice figure of merit of the radiator core for the benefit of heat transfer, but for unobstructed positions it appears that smooth straight air passages through the radiator should be provided.

Effects of Yawing Airplane Radiators.

Different radiators show different effects on being inclined at an angle to the direction of the air stream, but in general the results (for angles up to 30 deg.) are as follows:

(1) Decrease in air flow through the core;
(2) Increase in head resistance;
(3) In some cases slight increase in the heat transfer, for angles up to 20 deg. or 25 deg.

Wind-tunnel tests on radiators for aeronautic engines have usually been made with the face of the radiator normal to the direction of the wind, so that although local eddies might be set up, the general direction of the air stream was straight as it passed through the radiator. If the axes of the air passages are inclined at an angle with the general direction of the air stream, or, in other words, if the face of the radiator is not normal to the air stream, the properties of the radiator will be somewhat changed, and it is the purpose of this report to show the general form of these changes.

The effect of inclining the radiator at an angle with the air stream, or yawing the radiator, is of interest in connection with the following conditions:

(1) Radiator mounted in the propeller slip stream, where the air strikes the radiator at other angles than normal to its face.

(2) Radiator mounted in any position (such as the wing) where the axes of its passages for the air are not parallel to the direction of motion of the plane.

(3) Radiator pivoted about an axis perpendicular to the direction of motion of the airplane. This construction represents one method that has been suggested for the regulation of cooling capacity.

The effects of yawing a radiator through angles from 0 deg to 45 deg fall into three classes, namely, the effects on (1) air

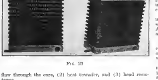


Fig. 21

flow through the core, (2) heat transfer, and (3) head resistance.

(1) Effect on Air Flow Through the Core.

For ordinary types of radiator the mass flow of air through the core is directly proportional to the free air speed (that is, to the speed of the air stream in which the radiator is placed) when the face of the radiator is normal to the air stream. Measurements of air flow have been made on two sections in yawed positions and the results obtained with one of the sections are shown in Plot 1, which indicates that the relation between mass flow of air through the core and free air speed is still linear between 30 and 90 m p h, but the line points below the origin. The two types tested are of square cell construction, about one-fourth inch in diameter.

A similar effect, but much more pronounced, was observed in the case of a single type of core when in its normal (not yawed) position. The result of this test is also shown in Plot 1. This type is made up with irregular shaped cells inclined at an angle of $4\frac{1}{2}$ deg to the normal to the face, alternate rows of cells being inclined on opposite sides of the normal. It is illustrated in the accompanying photograph.

The type G-4 and types that whistle in the air stream are the only radiators noted in which the air flow through the core is not directly proportional to the free air speed.

(2) Effect on Heat Transfer.

No tests have been made at this bureau to determine the effect of yawing the radiator on heat transfer, but a French report mentions a section (type not specified, but probably cellular) which showed an increase in heat transfer as the angle of yaw increased from 0 deg to 20 deg, and then a decrease, bringing the heat transfer back to its normal value with an angle of about 40 deg. The maximum increase over the normal value was about 7 per cent. The French report further states that "with radiators of water-plate type the increase in heat transfer is not so clearly shown, but the decrease in effectiveness is hardly perceptible below 40 deg."

A British report states that three honeycomb types, each 12 in square, showed a maximum increase in heat transfer of somewhat over 20 per cent with angles of yaw of about 45 deg. A large honeycomb section with 4.8 sq ft frontal area gave a maximum of about the same per cent at 25 deg.

(3) Effect on Head Resistance.

Plots 2 and 3, for $\frac{1}{4}$ in square cell (No 81) and $\frac{3}{8}$ in elliptical cell (No 73), respectively, are given as typical of ordinary cellular types. The head resistance increases rapidly with the angle of yaw up to at least 30 deg.

Plots 4 and 5 are for special types which show the variations in the form of the curves. The type No 80 has spiral air passages, and its head resistance shows very little change for angles up to about 30 deg. The type No 79, shown in the photographs, is the type whose peculiar air flow is mentioned above. This shows a large increase in head resistance with increase in angle of yaw, and in particular it shows a very sudden increase with small angles.

Industrial Arts Index

Our readers will be interested in learning that Aviation and Aeronautical Engineering is now indexed in the Industrial Arts Index, a publication that indexes every important article in more than a hundred and fifteen leading technical and industrial journals. The periodicals indexed have been selected by the subscribers of Industrial Arts Index as leaders in their respective fields. The list is increased from time to time by additions of magazines that are submitted to subscribers for their votes.

The Industrial Arts Index is issued ten times a year, is cumulated bi-monthly and quarterly, with a bound annual volume which is cumulated for the complete year at the end of each year. Every other year the annuals are cumulated in a two-year cumulation, thus reducing the number of annuals to be used when the entire service is consulted.

Albatross Parasol Monoplane (200 Hp Siemens Rotary). The Decrease of the Camber at Both Center Section and Wing Tips Is Noteworthy

THE HOME INSURANCE COMPANY NEW YORK

ELBRIDGE G. SNOW, President

Home Office: 95 William St., New York

AIRCRAFT INSURANCE

Against the Following Risks

1. FIRE AND TRANSPORTATION.
2. THEFT (Of the machine or any of its parts).
3. COLLISION (Damage sustained to the plane itself).
4. PROPERTY DAMAGE (Damage to the property of others).

SPECIAL HAZARDS

Windstorm, Cyclone, Tornado—Passenger Carrying Permit—Stranding and Sinking Clause—Demonstration Permit—Instruction Permit

AGENTS IN CITIES, TOWNS AND VILLAGES THROUGHOUT THE UNITED STATES AND ITS POSSESSIONS, AND IN CANADA, MEXICO, CUBA, PORTO RICO AND CENTRAL AMERICA

Aircraft, Automobile, Fire and Lightning, Explosion, Hail, Marine (Inland and Ocean), Parcel Post, Profits and Commissions, Registered Mail, Rents, Rental Values, Riot and Civil Commotion, Sprinkler Leakage, Tourists' Baggage, Use and Occupancy, Windstorm

STRENGTH REPUTATION SERVICE

Baker's A-A Castor Oil

Specially Refined for the Lubrication of AERONAUTICAL MOTORS

BAKER CASTOR OIL CO.
Founded 1857
The Oldest and Largest Manufacturers of Castor Oil in the United States
120 BROADWAY - - - NEW YORK

COVERS THE CONTINENT — JOHNS-MANVILLE SERVICE

Are you building a hangar?

JOHNS-MANVILLE Corrugated Asbestos Roofing, used for the roofs and side walls of hangars, gives weather-proof protection of splendid durability because it is immune to the corrosive action of sea-air, smoke or acid fumes —and it never needs painting for its asbestos surface is amply able to resist any climate.

Write for information about Johns-Manville Corrugated Asbestos Roofing — you will probably find it peculiarly suited to your needs.

H. W. JOHNS - MANVILLE CO.
Madison Avenue at 41st Street, New York City
10 Factories—Branches in 64 Large Cities
For Canada
CANADIAN JOHNS-MANVILLE CO. Ltd., Toronto

ANNOUNCEMENT

We are pleased to inform our many inquirers that we are now able to make immediate deliveries on standard types of

HAMILTON PROPELLERS OF QUALITY

Some choice territory still available to responsible distributors.

HAMILTON AERO MFG. CO.
MILWAUKEE, WIS.

Aluminum Company of America

General Sales Office, 2400 Oliver Building
PITTSBURGH, PA.

Producers of Aluminum

Manufacturers of

Electrical Conductors
for Industrial, Railway and Commercial Power Distribution

also

Ingot, Sheet, Tubing, Rod, Rivets, Moulding, Extruded Shapes

also

Litot Aluminum Solders and Flux

CANADA
Northern Aluminum Co., Ltd., Toronto

ENGLAND
Northern Aluminium Co., Ltd., London

LATIN AMERICA
Aluminum Co. of South America, Pittsburgh, Pa.

"The Spark Plug That Cleans Itself"

"The Plug with the Infinite Spark"

BREWSTER-GOLDSMITH CORPORATION
33 GOLD STREET, NEW YORK CITY

Edstrom Machinery Company

WAR DEPARTMENT
BUREAU OF AIRCRAFT PRODUCTION
AIRPLANE ENGINEERING DEPARTMENT
McCook Field, Dayton, Ohio, U. S. A.
REPORT Serial No. 646
on test of cable terminal connections made on the Edstrom Wire Wrapping Machine

Finished Products of the Edstrom Machines

"It is to be noted that out of ten unsoldered specimens sizes 1/8" to 5/32", only one failed at a load below the rated capacity of the cable. The 3/16" specimens served with copper wire failed at loads averaging 71 per cent of the full strength of the cable."

Note. The nine cables standing 100 per cent were wrapped with the special strength wrapping wire we use on all our work.

"The Edstrom Wire Wrapping Machine should be given a trial where such a machine is desired."

We can give you stronger, neater and better work at a great saving of cost to you.

Let us give you our price.

FACTORY:
Cary, Ill.
(Near Chicago)

PARAGON PROPELLERS

Highly Developed Dynopter Design
Special for J. N. Machines

The Economy Propeller Par Excellence

Price $45.00 F. O. B. Baltimore
For Metal Sheathing Add $12.00

These are a Special Development for O. X. Motors on J. N. Machines, now being made in large quantities and ready for immediate shipment on receipt of $15.00 deposit. C. O. D. for balance, with examination allowed before acceptance and safe delivery guaranteed. Every one bears the Paragon mark, with all that the mark implies. Get our General Booklet and List for other designs, etc. Write today.

AMERICAN PROPELLER & MFG. CO.
1261-9 Covington Street
Baltimore, Maryland, U. S. A.

INFORMATION IS CAPITAL

Every Weekly Issue of

AIRCRAFT JOURNAL

contains new ideas and fresh angles on the widening field of commercial aeronautics—information of real value to the manufacturer, pilot or prospective purchaser, as well as those who are investigating aviation possibilities.

It will pay you to keep currently informed of the progress of commercial aeronautics, by reading AIRCRAFT JOURNAL each week.

Fifty-two Issues Two Dollars
Twenty-six Issues One Dollar

THE GARDNER-MOFFAT CO., INC.
22 East Seventeenth Street, NEW YORK

AVOID THE FIRE HAZARD
and use
PHENIX FIREPROOF DOPE
on your Airplane

A REAL non-inflammable dope preventing the spreading of fire.

Specify Phenix Fireproof Dope on your airplane. Aluminum or clear.

PHENIX AIRCRAFT PRODUCTS CO.
WILLIAMSVILLE, N. Y.

Grand Rapids Vapor Kilns

are used by these aircraft concerns with absolute satisfaction.

Standard Aircraft Corporation
Fisher Body Corporation
American Propeller & Mfg. Co.
Alexandria Aircraft Corp.
Gallaudet Aircraft Corp
Thomas-Morse Aircraft Corp.

Submit your drying problem to experts who make a specialty of kiln design and are prepared to furnish and install all equipment and instruments.

GRAND RAPIDS VENEER WORKS
Grand Rapids, Michigan — Seattle, Washington

Warwick **NON-TEAR** *Aero-Cloth*

A SAFE CLOTH *for* FLYING

For Particulars Apply to
WELLINGTON SEARS & CO.
66 Worth Street, New York

Flottorp Manufacturing Co.
AIRCRAFT PROPELLERS
Established 1912

213 Lyon St., Grand Rapids, Michigan

Contractors to United States Government

PROPER instrument equipment assures greater safety, better performance, higher efficiency. It will pay you to investigate.

PIONEER INSTRUMENT COMPANY
136 Havemeyer Street Brooklyn NY

HALL-SCOTT

TYPE L-6
AIRPLANE ENGINES

Hall-Scott Motor Car Company
West Berkeley, California

The pioneer manufacture of airplane parts made from bar stock. Any and everything pertaining to the manufacture of airplanes.

Any Quantity

A. J. MEYER MANUFACTURING CO.
819 John Street — West Hoboken, N. J.

AIRPLANE INSURANCE
FOR THE
Manufacturer—Flyer

Fire—Collision—Damage to Property of Others
Legal Liability—Life—Personal Accident
Conservative Rates—Best Companies

PHONE—WRITE—WIRE

HARRY M. SIMON
Insurance Expert
81-83 Fulton St. — New York, N. Y.

INDEX TO ADVERTISERS

JONES TACHOMETERS

Acknowledged by experts as the
"BEST BY TEST"

Jones Aeroplane Tachometer

—was designed especially for the United States Navy Department for use in the war. Its splendid record of service, under all conditions, was demonstrated by the Famous Trans-Atlantic flight of the N C 1, N C 3 and N C 4. It is the lightest instrument of any type yet produced.

The Jones Aeroplane Tachometer comprises the Standard Jones Head, which is being widely used in commercial fields. This instrument is particularly adapted for use on special testing outfits, such as magneto and dynamometer test sets, etc. The dial is evenly spaced throughout, thus making possible quick and accurate readings of revolutions per minute.

The Jones Aeroplane Tachometer can be driven either by flexible shaft or belt, as preferred.

We have designed the *Jones Hand Tachometer* especially for portable use. This instrument has proven invaluable in *Cotton* and *Paper Mills* and *Machine*

Shops, etc. A special disc, one foot in circumference, can be supplied to show peripheral, or surface speed in feet per minute

Send to-day for a report of test by the United States Bureau of Standards, and for our new booklet.

JONES-MOTROLA, INC.
29 West 35th Street — New York

A. J. FISK, Special Representative, 865-867 Woodward Avenue, DETROIT, MICH — Southern Representative, I. W. BECKER, ATLANTA, GA

For Your Flying ←Boats Use

Upward of 5,000 gallons of Jeffery's Patent Waterproof Liquid Glue has been used by the U. S. Navy and War Department and as much more by the various manufacturers of seaplanes having government contracts.

L. W. Ferdinand & Co.
152 Kneeland Street
Boston, Mass., U. S. A.

LEARN TO FLY

in old established school under an instructor who has given instruction to more

AMERICAN ACES

than any other instructor.

Army Training Planes Used.
We Build Our Machines.

PRINCETON FLYING CLUB, Princeton, N. J.
WEST VIRGINIA AIRCRAFT CO., Wheeling, W. Va.
DAYTONA FLYING CLUB (Winter), Daytona, Fla.

FREDERICK W. BARKER

REGISTERED PATENT ATTORNEY

2 RECTOR STREET **NEW YORK**

Telephone 4174 Rector *Over 30 Years in Practice*

PRESIDENT
AERONAUTICAL SOCIETY OF AMERICA
FROM 1915 TO 1919

SPECIALTY. Patent Claims That Protect

CLASSIFIED ADVERTISING

10 Cents a word, minimum charge $2.00, payable in advance. Address replies to box numbers, care AVIATION AND AERONAUTICAL ENGINEERING, 22 East 17th Street, New York.

Capable "War Pilot" wants position flying. Thoroughly experienced on Handley-Pages, and all smaller types. C. R. HOARE, 659 Drexel Avenue, Detroit.

**CONSULTING
AERONAUTICAL ENGINEERS**

AN INDEPENDENT ORGANIZATION OF SPECIALIZED AERONAUTICAL ENGINEERS ENGAGED IN THE SCIENTIFIC AND PRACTICAL DEVELOPMENT OF AERONAUTICS BY CONSULTATION, DESIGN EXPERIMENTAL RESEARCH AND TESTING

ALEXANDER KLEMIN

22 East 17th Street **New York**

An Unusual Opportunity

To Complete Your Files of

Aviation and Aeronautical Engineering

We have a limited number of bound volumes covering the period from August 1, 1916 to January 15, 1919, containing in every issue aeronautical engineering information of fundamental value. These volumes comprise a complete record of the science of aviation during the period of the great development of aerial warfare.

VOL. I	$25.00
VOL. II	10.00
VOL. III	5.00
VOL. IV	5.00
VOL. V	5.00

Also the following sets not bound

VOL. III	3.00
VOL. IV	3.00
VOL. V	3.00
VOL. VI	3.00
VOL. VII	3.00

THE GARDNER, MOFFAT COMPANY, Inc.

22 East 17th Street **New York City**

Aeronautical Engineering and Airplane Design

By *LIEUTENANT ALEXANDER KLEMIN*

Air Service Aircraft Production, U. S. A. in Charge Aeronautical Research Department, Airplane Engineering Department. Until entering military service in the Department of Aeronautics, Massachusetts Institute of Technology, and Technical Editor of AVIATION AND AERONAUTICAL ENGINEERING In two parts.

PART 1. AERODYNAMICAL THEORY AND DATA

Modern Aerodynamical Laboratories
Elements of Aerodynamical Theory
Sustention and Resistance of Wing Surfaces
Comparison of Standard Wing Sections
Variations in Profile and Plan Form of Wing Sections
Study of Pressure Distribution
Biplane Combinations
Triplane Combinations—Uses of Negative Tail Surfaces
Resistance of Various Airplane Parts
Resistance and Comparative Merits of Airplane Struts
Resistance and Performance
Resistance Computations—Preliminary Wing Selections

PART 2. AIRPLANE DESIGN

Classification of Main Data for Modern Airplanes; Unarmed Land Reconnaissance Machines; Land Training Machines
Land Pursuit Machines, Land Gun Carrying Machine; Twin-Engined All round Machine
Estimate of Weight Distribution
Engine and Radiator Data
Materials in Airplane Construction
Worst Dynamic Loads, Factors of Safety
Preliminary Design of Secondary Training Machine
General Principles of Chassis Design
Type Sketches of Secondary Training Machine—General Principles of Body Design
Wing Structure Analysis for Biplanes
Notes on Aerial Propellers

Price, Postpaid, in the United States, $5.00 Net

The Gardner, Moffat Company, Inc., Publishers

22 East 17th Street, New York City

AIRPLANE TRANSPORTATION

The world's increasing business demands quicker distribution and closer links of association which are possible only through greater and faster transportation facilities. Airplane transportation today provides enlarged distribution and thus makes possible the economy of mass production. Airplanes are no longer merely military requisites. They are commercial necessities, *for they are transportation.*

People in all lines of activities are coming more and more to the realization of the practicability of the airplane. The unusual opportunities an airplane passenger, mail or express service offers as a profitable investment should appeal, when fully understood, to capital.

Information and analysis of investment and profit, pertaining to the operation of any contemplated airplane transportation service will be gladly furnished by the Bureau of Martin Airplane Transportation Information.

MARTIN U.S.A.

TRADE MARK

THE GLENN L. MARTIN COMPANY

CLEVELAND